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A Flood Risk Assessment of the San Jacinto River Waste Pit Superfund Site

CENTER FOR TEXAS BEACHES AND SHORES – TEXAS A&M UNIVERSITY GALVESTON

WITH: SAMUEL D. BRODY, PHD

RUSSELL BLESSING, KAYODE ATOBA, WILL MOBLEY, MORGAN WILSON

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CONTENTS

FIGURES

INTRODUCTION

The San Jacinto River Waste Pits site, located in Channelview, Texas, consists of a series of impoundments (pits) that were constructed on the west bank of the San Jacinto River near the Interstate-10 Bridge between October 8, 1964 and February 15, 1973. Paper mill wastes containing polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were dispensed into these pits during the 1960s and 1970s. Since their construction, groundwater extraction, dredging, sand mining, and river currents and surge have eroded the containment berm, which has allowed a portion of the impoundments to be submerged under water (Anchor, 2013).

Recent studies have indicated that high-flow events (e.g. hurricanes and tropical storms) have undermined the ability of the waste pits to retain their chemicals and may have transported dioxin-contaminated sediments into the surrounded areas along the Houston Ship Channel and the Galveston Bay (Bedient, 2013; Integral and Anchor, 2013). Although it is uncertain how much of these dioxins are leaking into the river, studies have corroborated the idea that the chemicals are leaching from the pits (Rifai, 2006). Rifai (2006) found elevated levels of dioxins in fish and crabs near the site as a result of bioaccumulation. Before Rifai's study the Texas Department of State Health Services issued a public notice in 2001 urging consumers to limit their consumption of fish caught from the San Jacinto River. In a broader context, the San Jacinto does not meet the health standards for several toxic chemicals and is nationally recognized by the EPA as being severely impaired.

In 2008, the San Jacinto Waste Pits were placed on the National Priorities List of Superfund Sites due to the high level of dioxin contamination detected near the site. These chemicals pose a severe risk to humans and the environment as dioxins are a known Group 1 carcinogen that can impose deleterious health effects. As a result, there has been much concern regarding human exposure with the primary pathways being: oral ingestion through hand contact and subsequent hand-to-mouth activities, dermal absorption of site contaminants through skin contact with sediments, and ingestion of fish or crabs caught near the site.

Purpose of the Study

Based on existing data, it is becoming increasingly evident that the waste pits are likely leaking dioxins into the San Jacinto River (Rifai, 2006). Despite this evidence, it remains unclear which human communities could be potentially impacted by these carcinogenic materials. Moreover, no studies have explicitly examined the exposure of these waste pits to riverine and surge-based flood events, which are likely the primary driver of the deterioration and subsequent release of pollutants from the superfund site. Existing reports only superficially address the flood risk associated with the site and do not consider the the impact of previous events, changing risk conditions, or potential wave action from storm surge. Moreover, a thorough socioeconomic profile and consideration of future growth is absent (Anchor QEA, LLC., 2013)

This report will address this lack of research by examining three major issues associated with the superfund site: (1) the physical and environmental context; (2) the socio-economic context; and (3) the level of flood risk. The physical context addresses the dynamic nature of where the site is located by discussing changing climatic patterns, tidal influences, subsidence, and erosion. Understanding the socio-economic characteristics of the surrounding neighborhoods offers critical insight regarding the vulnerability of the potentially-affected population as well as their ability to recover from a disturbance. Because the socio-economic information examines only one snapshot in time, we augment the analysis with both historical land use and land cover (LULC) change to illustrate that the surrounding area falls within a rapidly developing region that will continue to grow well into the future. Lastly, combining the above information with a risk assessment of the superfund site to catastrophic floods provides an accurate, contextually relevant, and dynamic description of the potential adverse effects of the pits on the surrounding human and natural environments.

BACKGROUND

In 1965 and 1966, the San Jacinto River Waste Pits were created for disposal of paper mill waste. Solid and liquid waste contaminated with polychlorinated dibenzo-p-dioxins, polychlorinated furans, and some metals from Champion Paper, Inc. in Pasadena, Texas were disposed of in the impoundments north of Interstate-10, west of the main channel of the San Jacinto River, and east of the City of Houston, between Channelview and Highlands. Dioxins and furans are classified as "hazardous substances" by Section 101 (14) of CERCLA, 42 U.S.C §9601 (14), which are defined as:

> “Hazardous substances are defined as products that are toxic, corrosive, flammable, irritant, or radioactive. They are any substances that could cause or significantly increase mortality or seriously irreversible or incapacitating illness. Hazardous substances pose substantial threats to human health and the environment when improperly treated, stored, transported, or disposed of.”

Throughout the 1970s and 1980s, there were physical changes at the site, including subsidence that resulted in partial submergence of the impoundments into the San Jacinto River (ATSDR, 2012). When subsidence occurred, dioxin-laden wastes were exposed to the river. Dioxins are insoluble in water, so they tend to bind to the soil and sediments, as well as pulp from paper mill waste, which are ingested in small animals and concentrate up the food web. It was not until April 2005 that Texas Parks and Wildlife (TPWD) were notified that there were partially submerged waste pits in the river, and TPWD subsequently notified the Texas Commission of Environmental Quality (TCEQ). On March 19, 2008 the site was placed on the U.S. Environmental Protection Agency's (EPA) National Priority List (NPL). The NPL is a list of uncontrolled or abandoned hazardous waste sites identified for long-term cleanup under the Federal Superfund program. From April 2010 to July 2011, short-term stabilization caps were constructed to temporarily address the leakage of dioxins into the San Jacinto River. Currently, the debate regarding this site is whether or not the site should be moved, or if the caps should become a permanent fixture to prevent further leakage.

According to *The Pasadena Citizen*, Harris County Attorney Vince Ryan is suing International Paper, Inc., Marsh and Mclennan Inc. Companies, and Waste Management for polluting the San Jacinto River. Ryan states, "the Waste Pits are located in an area of the San Jacinto River that is the locale of boating, swimming, camping, commercial and recreational fishing. Removal of the source material from the Waste Pits and the river sediment is the only way" to end exposure to toxic chemicals. The case is currently pending in state district court and is set for trial in September, 2014.

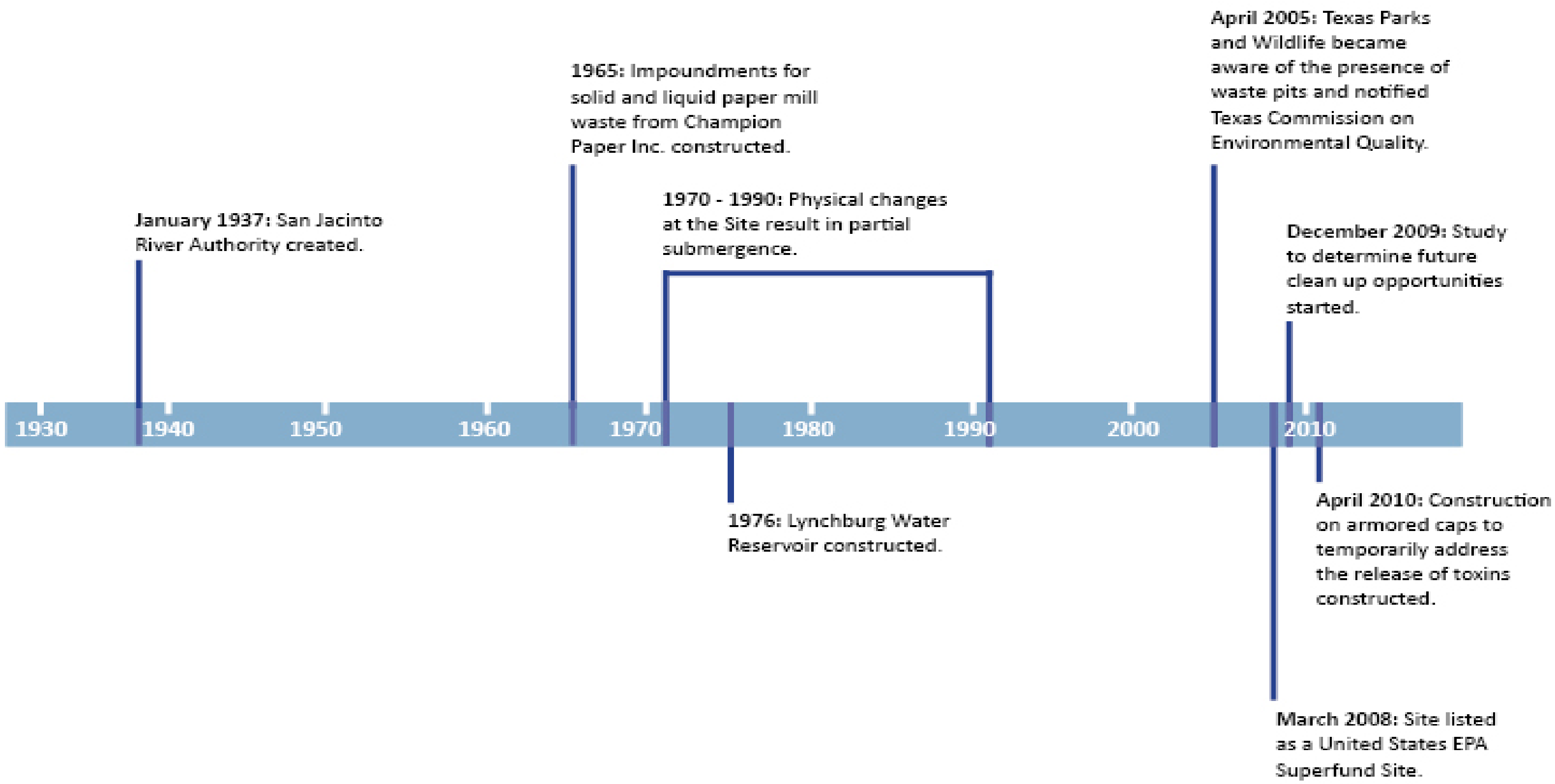


Figure 1. Timeline of Events.

Dioxins

Dioxins and furans are compounds that are known to cause cancer in humans (Bertazzi et al., 2001; Akhtar et al., 2004). Non-cancer effects of dioxins include adverse female reproductive effects, subtle changes in immune system components and developmental effects (Stephen et al., 1998; Venna et al., 1996; Kansler et al., 2007). The location of the San Jacinto Superfund Site at the mouth of the river is a major concern, due to bioaccumulation in marine ecosystems (Ronk & Guven, 2013).

Dioxins and furans are referred to as persistent organic pollutants (POPs) or hydrophobic organic compounds (HOCs) that are introduced into the environment via agricultural and industrial activities (Haynes & Johnson, 2000; Torres et. al., 2008). The Baseline Ecological Risk Assessment performed by Houston Advanced Research Center in 2013 sampled sediment, marine animal tissue, and surface water from areas near the south impoundment (Ronk & Guven, 2013). The major threat that POPs and HOCs have on marine and human ecosystems is the bioaccumulation effect (Micheletti et. al, 2007; Haynes & Johnson, 2000; Ronk & Guven, 2013; Torres et al, 2008). Bioaccumulation is the process of chemicals or compounds accumulating as it travels up the food web (EPA, 1999). The ecological risk affects humans when recreational fishermen consume locally caught contaminated fish; however, the Texas Department of State Health Services has issued a fish and shellfish consumption advisory. The notice, issued 26 June 2013, advises people near the Galveston Bay Estuary to limit their consumption of blue crab, catfish, and spotted sea trout to one meal per month from this area (Texas Department of State Health Services, 2013). Dioxins have very low solubility, meaning they do not readily dissolve in water. The only groundwater with significant dioxin levels was shallow and directly under the Superfund Site (Beauchamp, 2013). A report for the Texas Department of State Health Services and the Agency for Toxic Substances and Disease Registry suggested that there are very few ways that the toxic compounds could enter a person's body. ATSDR (2012) outlines three pathways that could potentially expose humans to toxic contaminants:

1. Oral Ingestions of sediments
2. Dermal absorption of site contaminants
3. Ingestion of fish or crabs caught near the site

It should also be noted that the San Jacinto River Waste Pits Superfund Site Bioaccumulation Modeling report published by Integral Consulting (2010) for McGinnes Industrial Maintenance Corporation suggested that the dioxin and furan concentrations in fish and crab tissues collected from the Site are similar to concentrations in specimens tested in other areas. This finding suggests that POP compounds in tissues may be more dependent on biological factors than environmental or exposure factors (Integral Consulting, 2010).

Despite varying opinions, it is important to understand there is a very real risk that dioxin-contaminated sediment could be scoured from the site due to surge or overland flow and dispersed into surrounding areas. Moreover, subsidence, flooding and hurricane surge will continue to happen and will likely continue to degrade the structural integrity and viability of these waste pits leaving more potential for dioxins to make their way into the natural environment. Due to these risks it is imperative that future decisions regarding the waste pits take into account the physical, social, and flood related contexts of the site.

STUDY AREA

The San Jacinto Waste Pits are located at the mouth of the San Jacinto River, north of the Galveston Bay, and approximately 20 miles east of downtown Houston, Texas (Figure 2). The San Jacinto River Watershed drains approximately 4,500 square miles of eastern Harris County, which carries approximately 2 million acre-feet of run-off per year (Bedient, 2013). The river originates in Huntsville, Texas and flows southeast towards Houston where it joins the Houston Ship Channel before emptying into the Galveston Bay. The Galveston Bay is roughly 600 square miles in size and is the second most productive fishery in the United States and hosts one of the most diverse bird populations in the world (Martin, 2006). Critical to the health of the Galveston Bay ecosystems are the freshwater inflows from the Trinity and San Jacinto Rivers (TE&S, 2007).

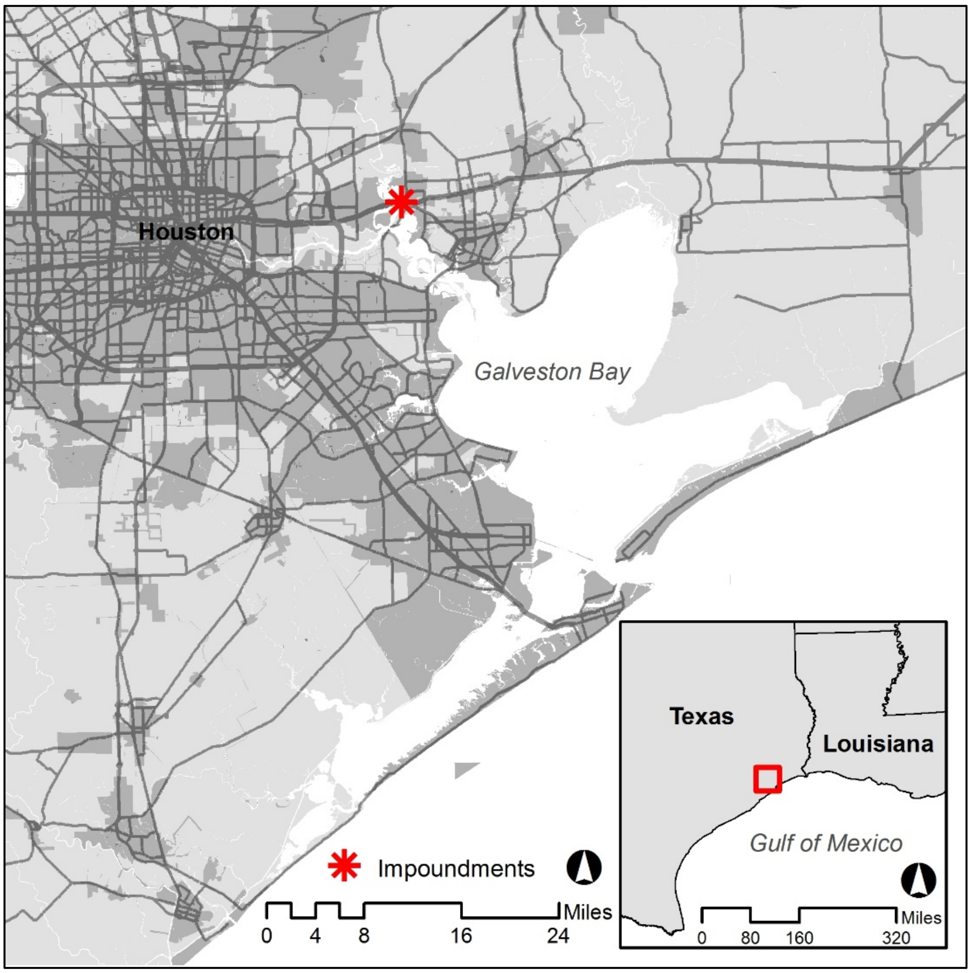


Figure 2. Large-Scale Study Area.

The San Jacinto River does not meet national standards for several toxic chemical and bacteria Total Maximum Daily Loads (TMDLs) and has not met these standards since 2002 as noted in each edition of the Texas Water Quality Integrated Report for Clean Water. In 2001, the Texas Department of State Health Services (DSHS) issued a public notice advising consumers to limit their consumption of fish caught in the San Jacinto River. The advisory was issued because the DSHS had determined that the concentrations of organochlorine pesticides, PCBs, and dioxins in fish tissues posed an unacceptable risk to human health (TCEQ, 2014).

The study area for the flood risk assessment includes the area within approximately a 5 mile radius directly surrounding the Superfund site, including the U.S. Census designated places of Channelview, Highlands, Baytown, and Pasadena (Figure 3). This area includes an entrance into the Houston Ship Channel which is located southwest of the waste pits with the Upper San Jacinto Bay to the south.

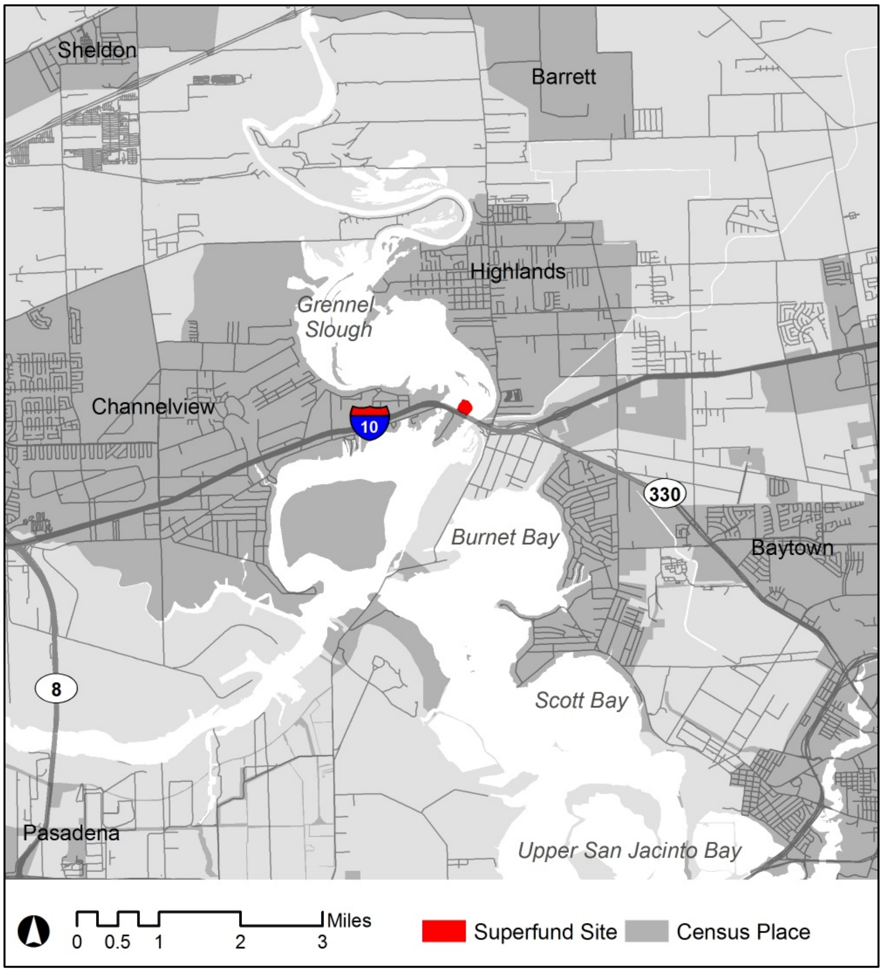


Figure 3. Study Area for Flood Risk Assessment.

The waste pits site consists of three major impoundments that are located on a sand bar in the San Jacinto River just north of I-10 (Figure 4). The waste pits were originally constructed from earthen dikes to separate them from the river. Since construction, the waste pits have considerably shrank in size due to erosion and subsidence and were recently structurally reinforced with an armored cap and a geomembrane due to concerns regarding the leakage of dioxins. These impoundments are approximately 14 acres in size, and are partially submerged in the San Jacinto River.

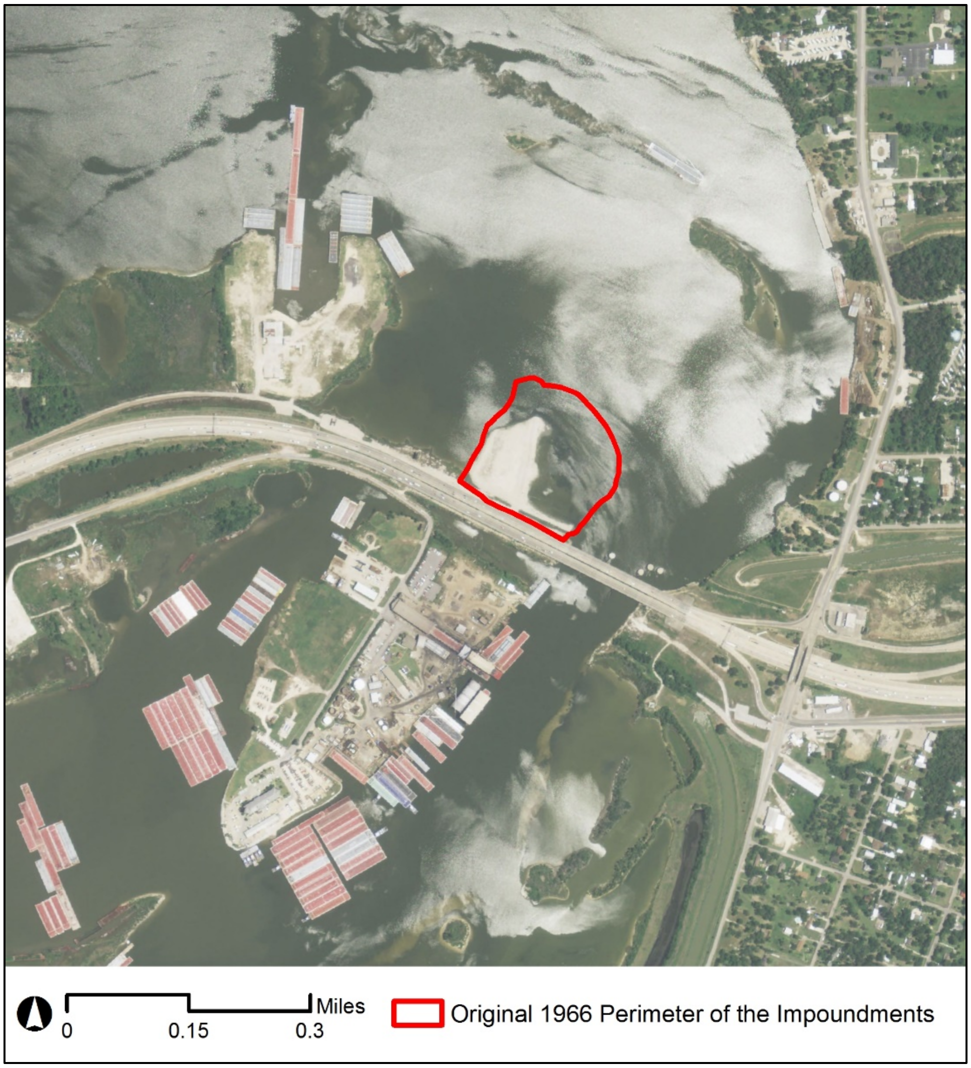


Figure 4. Small-Scale Study Area.

FLOOD RISK ASSESSMENT

Flood risk is inherently difficult to predict, as it requires the integration of three dynamic factors: (1) hazard, (2) exposure, and (3) vulnerability. Each of these factors are not static, but, rather, are constantly changing due to human development, storms, and climate change. As each of these factors change, so too does the level of risk. In this conceptualization of risk, *hazard* is defined as the occurrence of a hydrologic flood event with a given probability (i.e. return period). *Exposure* is driven by human actions and decisions and is typically represented by the amount of exposed assets within hazardous zones (e.g. the 100-year floodplain). *Vulnerability* represents the degree to which an asset is impacted when exposed to a hazardous event.

The San Jacinto Waste Pits are located in an area where all three of these factors have been continuously changing since construction. As a result, what may have initially been perceived as a low-risk situation has significantly increased over time. This assessment of flood risk focuses on the area within approximately 5 miles of the waste pits that could potentially be affected by the release of hazardous chemicals. The report integrates and discusses the following three risk factors associated with flood impacts in proximity to the site: (1) physical risk; (2) socio-economic risk; and (3) flood impacts.

Physical Risk

The San Jacinto Waste Pits are located in an area that is susceptible to multiple physical threats associated with flooding. First, the waste pits are located in a recently FEMA-designated VE Floodway Zone, which is subject to inundation by the 1-percent-annual-chance flood event (one percent chance of flooding in any year) with additional hazards due to storm-induced velocity wave action. Properties in this zone also have 26 percent chance of flooding over the life of a 30-year mortgage. Moreover, the Base Flood Elevation (BFE) for the waste pit location - the elevation of surface water resulting from a flood that has a 1 percent chance of equaling or exceeding that level in any given year - has been recently measured at 19 feet. Given the low-lying condition of the waste pit (the site is actually partially submerged), the risk of inundation coinciding with significant wave action is very high.

Second, the position of the site close to the mouth of Galveston Bay is especially problematic from a storm surge standpoint, further exacerbating the physical risk profile. Tropical and extra-tropical storm events can push water from the Gulf of Mexico into Galveston Bay where the highest tidal depths occur at the mouths of major rivers and freshwater inflows (TE&S, 2007). National Oceanic and Atmospheric Administration (NOAA) surge models for a category 3 storm striking Galveston Bay during high tide show surge levels at the waste pit site reaching 23 feet. A category 5 storm hitting the Bay during similar conditions would produce a storm tide of up to 33 feet. Keim, Muller & Stone, (2007) also derived an average return period of 3 years for tropical storms, 8 years for all Hurricanes, and 26 years for hurricanes category 3-5 for Galveston, Texas. Researchers at NOAAs National Hurricane Center corroborate this estimate, predicting the return period for a major hurricane (category 3) striking Galveston Bay at 25 years (http://www.nhc.noaa.gov/climo/).

Third, the extent and potential impact of storm surge will be exacerbated by both eustatic sea level rise and relative sea level rise in which ocean level increased relative to subsidence. The instrumental record for Galveston's Pier 21 "has recorded a 0.60 meter increase in relative sea level over the last 100 years" (Yoskowitz, Gibeaut, & McKenzie, 2009). In their study of the effect of sea level rise on flooding, Warner & Tissot (2012), computed storm probabilities for every 25-year interval, starting from year 2025. The researchers observed that exceedance probabilities for storm surge are increasing, especially for small-scale events. For example, the annual probability of an event comparable in size to hurricane Rita occurring in 2025 increases from 16% to 26%, and to 62% in 2050 due to sea level rise. The study also revealed that by the end of the century, the current return period of 6.6 years for hurricane Rita would increase to an annual event based on a conservative scenario of seal level rise, and by 2100 exceedance probabilities for large events such as hurricane Ike would double. Thus, these historic storm events impacting Galveston Bay in the past will have a higher occurrence rate in the future given the changing climatological conditions.

Fourth, sea level rise and associated increase in tidal levels is often attributed to climate change. However, subsidence and erosion also plays a vital role in the physical vulnerability around the waste pit site. Erosion was particularly evident as the site was originally constructed using river sand to separate the impoundments from the river. This river sand is highly permeable and extremely susceptible to erosion resulting in the leakage of contaminants into the San Jacinto River, especially when inundated

(Bedient, 2013). Bawden, Sneed, Stork, & Galloway (2003) categorized the Houston-Galveston Bay area as having been adversely affected by subsidence more than any other metropolitan area in the United States (U.S.), in large part due to ground water and oil and gas extraction. According to the Harris-Galveston Subsidence District (HGSD), the critical land areas around the Galveston Bay had a subsidence of about 10ft since 1906, with areas that have a heavy presence of industrial and petrochemical uses experiencing the highest level of subsidence since the Second World War (HGSD, 2014). The HGSD report also indicated that the subsidence has increased the frequency and severity of flooding- in fact, the Brownwood subdivision in Baytown, just about 3 miles south-east of the superfund site was totally abandoned due to subsidence and continual flooding (HGSD, 2014). An examination of historic aerial imagery indicates that the entirety of the superfund site was once above the height of the river, but is now partially inundated (Figure 5). The areas directly around the site have also subsided by 6ft from 1906-1978 and by 0.5ft from 1973-2010 (Bedient, 2013). When combined with other physical risk factors, subsidence in this area increases vulnerability of the superfund site to inundation from floods and potential exposure of residents living in the surrounding area.

Finally, the San Jacinto waste pits are also vulnerable to inundation from precipitation events where runoff, exacerbated by development overflows the banks of the river. High-peak flows from regional runoff frequently occur in the region of the San Jacinto River. In extreme circumstances, the amount of rainfall can exceed 12 inches within 24 hours. Severe tropical storms can cause large amounts of surface runoff that can produce high volume and velocity flows at the waste site. For example, a major flood in 1994 caused the San Jacinto River to rise by nearly 27 feet resulting in rapidly moving water with scouring flows. These large rainfall events can easily submerge the waste pits, causing them to overtop their levees and possibly spill contaminants into the San Jacinto River.

When taken together hurricane frequency, storm surge, sea level rise, and subsidence make the low-lying San Jacinto Waste Pits extremely vulnerable to inundation and erosive events.

Figure 5. Historical Imagery Illustrating Erosion of the Waste Pit Site.

Socio-Economic Risk

A large amount of work has been done on the presence of Dioxin-based pollutants within the San Jacinto River waste pits, but little if any analysis has been conducted on the socioeconomic conditions surrounding the site, despite the fact that development has significantly increased the number of people at risk from potential contamination during a flooding event. This section examines land use and sociodemographic trends near the waste site to provide a greater contextual understanding of the potential for human exposure and associated adverse effects.

Land Use & Land Cover Change

Residential development was somewhat limited when the San Jacinto River waste pits were constructed in the 1960’s and 70’s. However, unanticipated development over the last 50 years has significantly increased the number of residents in close proximity to the site, raising the potential for negative health impacts.

High population growth (125,185 people from 2011-2012) (Pulsinelli 2013) and a reliance on private transportation has forced development in Houston outwards from the central urban core. Our assessment of land cover change using data from the Coastal Change Analysis Program (CCAP) reveals that a significant amount of development occurred within approximately 5 miles of the waste pits between 1996 and 2011 (Figure 6). Three development classes were assessed surrounding the site based on percentage of impervious surface cover: low (21%-49%), medium (50%-79%), and high (80%-100%). In total, there was roughly 7.2 square miles of development within the study area. Most of this additional development was residential, identified as new neighborhood clusters in Channelview, Baytown, The Highlands, and Sheldon. The remaining new development consisted was a mixture of industrial development around the ship channel and new transportation corridors (e.g. Spur 330).

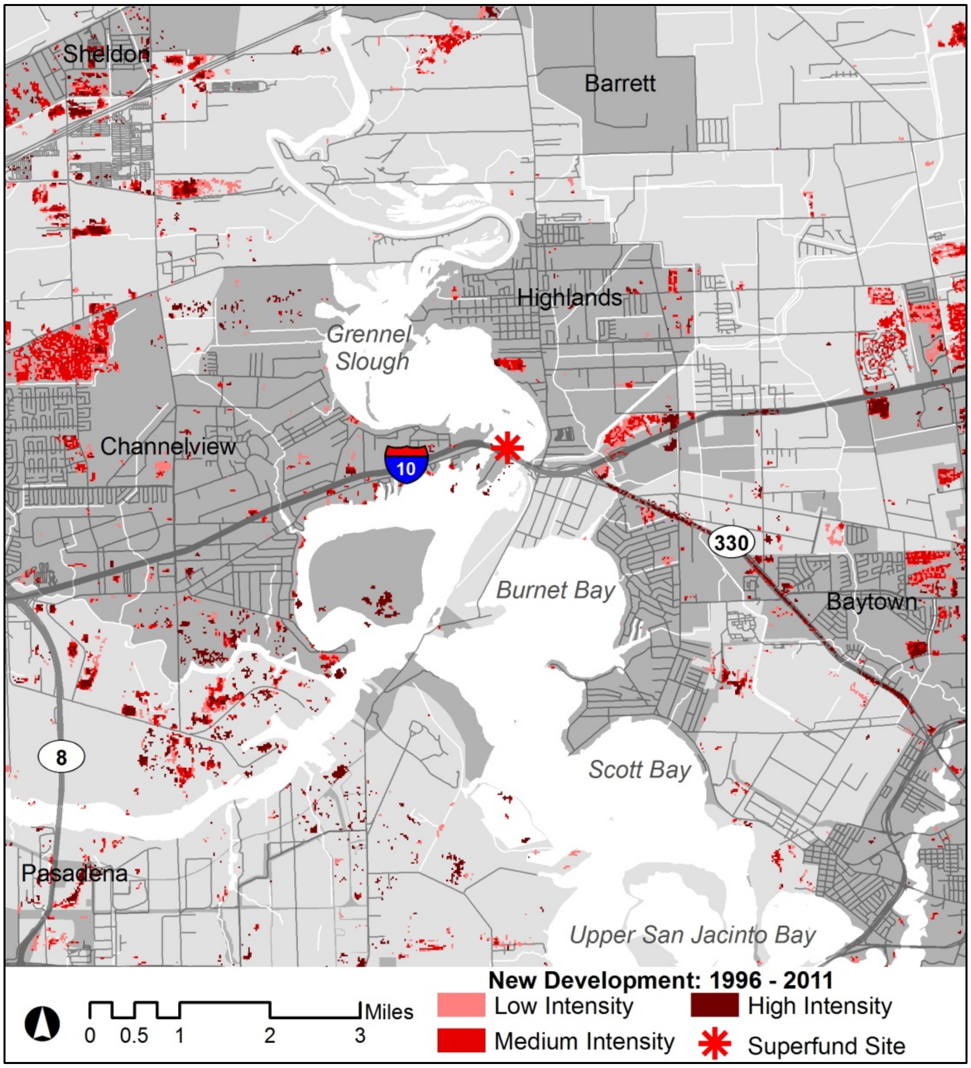


Figure 6. New Development from 1996 to 2011.

As shown in Figure 7, the current developed area surrounding the San Jacinto River site is primarily a mixture of industrial and residential land use. South of the site is dominated by industrial parcels because of the close proximity to the Houston Ship Channel. Residential areas follow along I-10, north of the industrial properties. The area north of the residential corridor is currently open space and undeveloped land with pockets of residential and industrial land uses.

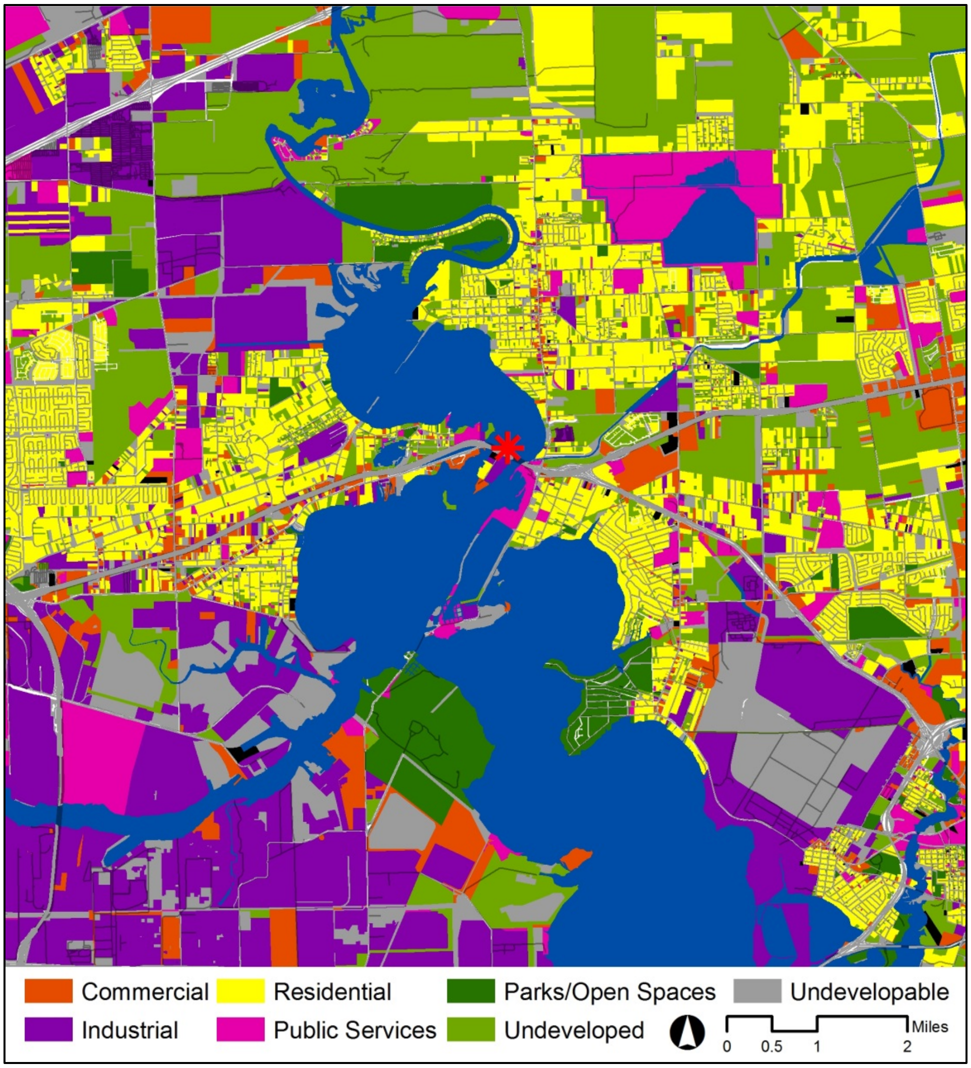


Figure 7. 2014 Land Use (HGAC, 2013)

Residential growth patterns are expected to continue in the immediate area. As indicated in Figure 8, projections out to 2040 conducted by the Houston Galveston Area Council (HGAC) indicate that development will expand north of Interstate-10 and throughout the northeast east portion of the waste pit site. Industrial infill is predicted to the northwest of the site. Projected development in these areas will increase the number of people at risk to flooding, inundation, and potential contamination. The conversion of open space and undeveloped land will also add impervious surfaces, which will likely increase the number and intensity of inland flooding events (Brody, Zahran et al. 2008). Moreover, development near the coast will increase the number of people at risk from storm surge. We address the direct impacts of both riverine flooding and current and future coastal surge impacts in a following section.

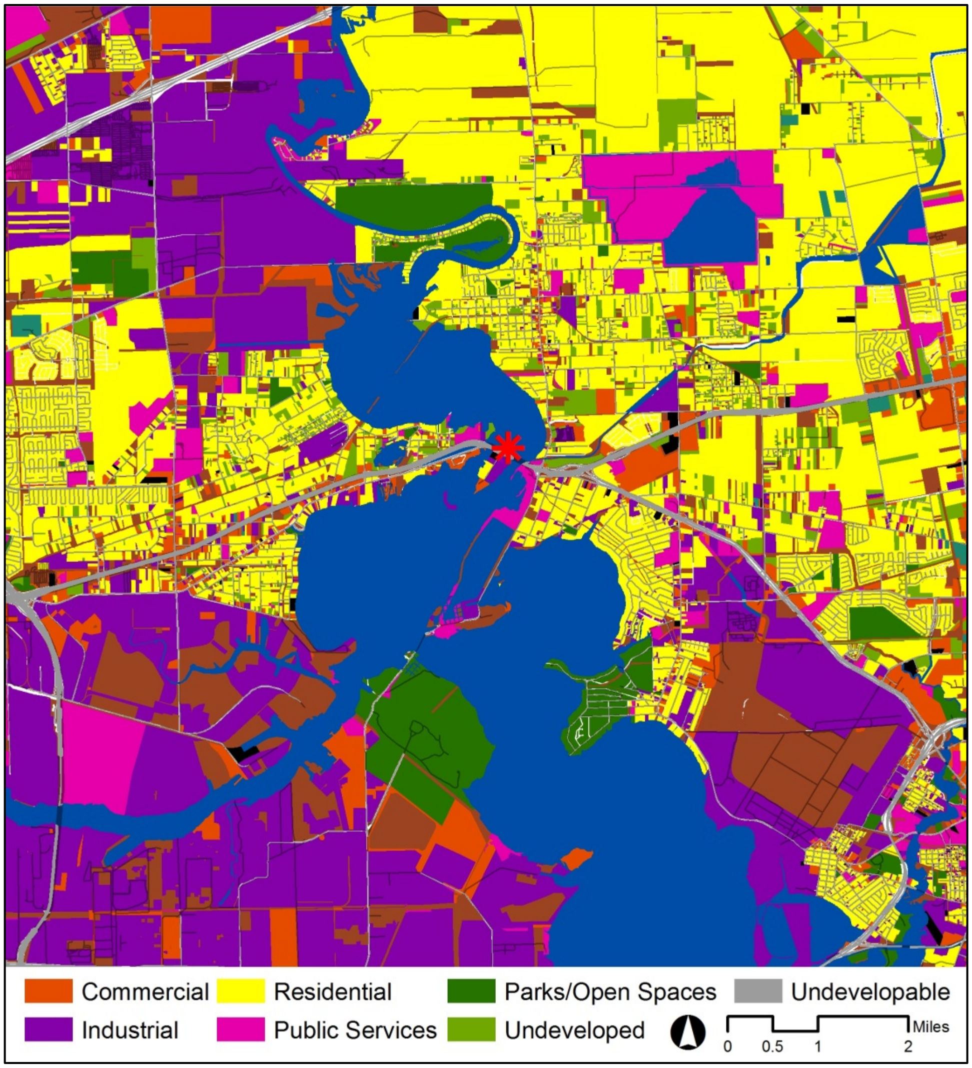


Figure 8. Projected 2040 Land Use (HGAC, 2013).

Population Characteristics

Assessing the characteristics of the population surrounding the waste pit site helps identify which segments are particularly vulnerable to flooding (Cutter and Emrich 2006). Socially-vulnerable populations are slower to recover from disasters (Peacock, Grover et al. 2011), and are more impacted by disasters (Zahran, Brody et al. 2008). Thus, socially vulnerable areas are generally more affected by inundation and do not have the resources to recover leaving a larger population at risk from dioxins.

This assessment uses data previously collected on social vulnerability with the following dimensions: Potential Child Care Needs, Potential Elder Care Needs, Potential Transportation Needs, Potential housing Needs, and Potential Civic Capacity Needs (Peacock, Grover et al. 2011). These dimensions are measured using 17 individual variables collected from the American Community Survey, all of which were aggregated at the Census Block Group level (Table 1). Once calculated, these dimensions were combined to create a social vulnerability index, that when mapped, elucidates the spatial pattern of environmental inequity.

Table 1. Social Vulnerability Index Measurement.

Variables	Dimensions	Index
1. Single parent households with children 2. Children with age below 5	Potential Child Care needs	**Social Vulnerability Index**
3. Elders with age above 65 4. Elders (65+) below poverty level	Elder Care Needs	
5. Public transportation dependency (workers using public transportation) 6. Occupied housing units without a vehicle	Public Transportation Needs	
7. Vacant housing units 8. Persons in renter occupied housing units 9. Race/Ethnicity (non-White population) 10. People in group quarters 11. Housing units built 20 years ago 12. Mobile homes 13. Persons in poverty	Temporary Shelter and Housing Recovery needs	
14. Occupied housing units without a telephone 15. School enrollment less than high school 16. Labor force (16+) unemployed 17. People (5+) speak English not well or not at all	Civic Capacity	

There are approximately 16,700 people living within in a 5 mile radius of the superfund site. Population densities directly adjacent to the San Jacinto River range from 1.3 people/sq. miles to 9.2 people/sq. miles, which is fairly dispersed compared to a traditional urban core. However, one of the block groups containing the highest population density in the study area is located directly north-west of the site. In contrast, the block group directly south of the site has one of the lowest population densities (1.3 people/square mile). The elderly population and the population under five years of age are dispersed throughout the study area, where the highest percentages of these populations are located less than five miles from the site. According to the U.S. Department of Health and Human Services, the poverty guideline for a family/household of 4 people is $23,850 (DHHS, 2014). While the average household income in the study area is $47,396, the populations that live below the poverty guideline tend to live in block groups closest to the Superfund Site (refer to the Appendix for maps of the individual variables discussed above).

The variables listed in Table 1 were used to generate a Social Vulnerability Index (SVI) at the Census Block Group level (Figure 9). Overall, Baytown has the highest degree of social vulnerability to floods, with high population concentrations in the southeast portion of the jurisdiction and a large area around Spur 330 (indicated in red as 'very high'). Other areas with 'high' social vulnerability include the parts of Channelview bordering the San Jacinto River and extending northward into the unincorporated regions around the cities of Sheldon and Barrett.

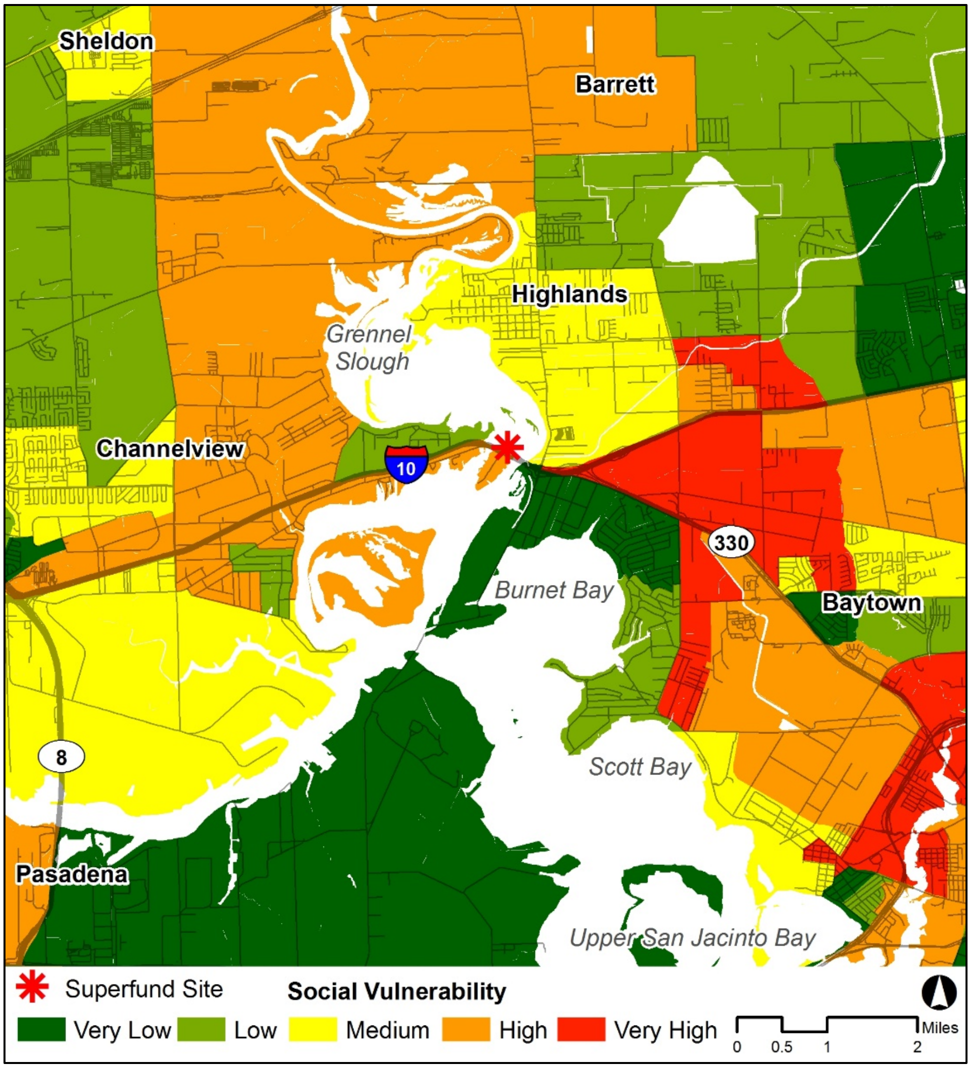


Figure 9. Social Vulnerability Index.

The level of social vulnerability within the study area is likely driven by the percentage of population that is either below 5 or above 65 years of age. Of particular concern is the population under 5 (Figure 10), as studies has shown that nursing infants consume about 50 times more dioxin per day than adults due the prevalence of dioxins accumulating in breast milk (Papke, 1998; Schecter et al., 1994). Moreover, it is estimated that roughly 10-14% of exposure to dioxins occurs via nursing (Patadin et al., 1999; Schecter et al., 1996).

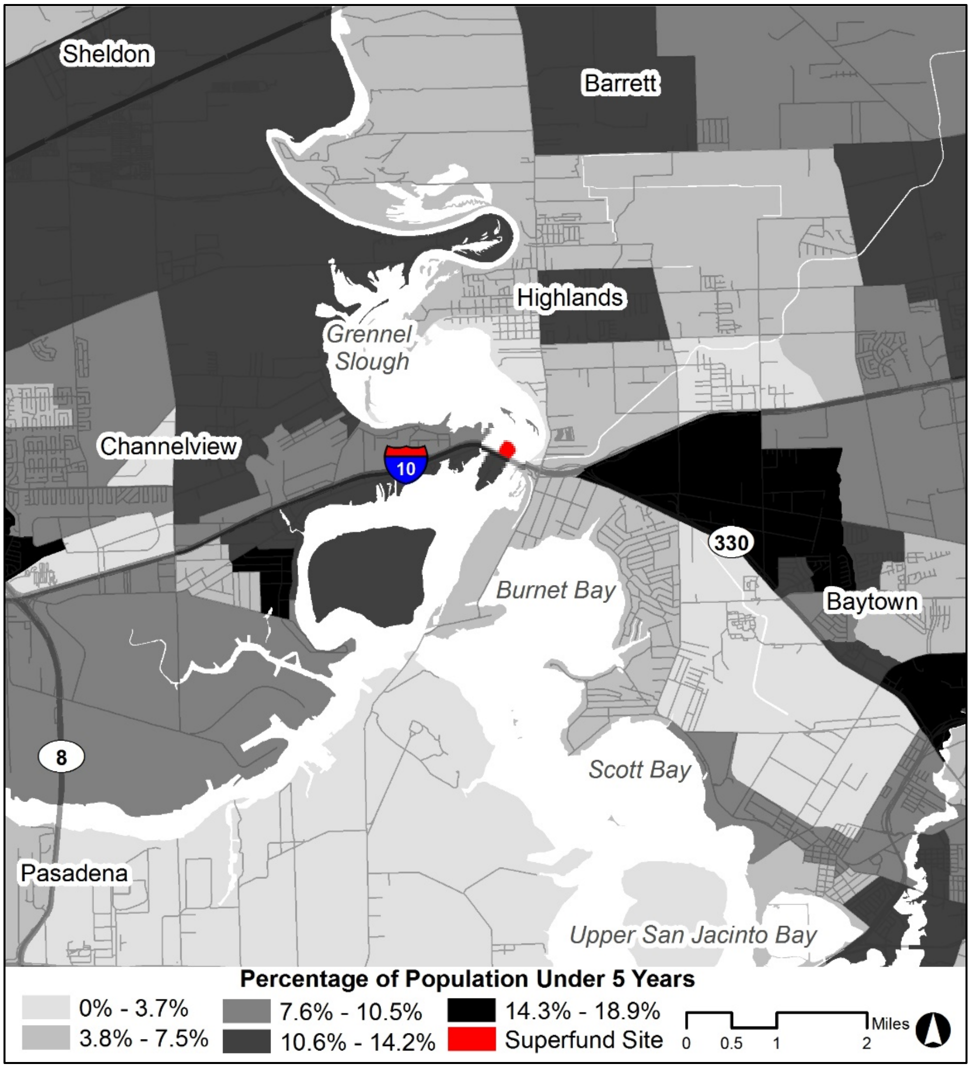


Figure 10. Percentage of Population Below 5 Years of Age by Block Group.

Lastly, another key trend stemming from the socioeconomic analysis is that the populations with high social vulnerability are located in areas most susceptible to storm surge and flooding. These populations would not only be most sensitive to dioxin exposure, but also have the most difficult time evacuating and recovering from a flood event, further exacerbating the adverse impacts to this segment of the community. That said, exposure to the dioxins could potentially occur without the presence of a major storm due to the documented potential for chemical leakage. Rather, it is the erosive and structurally degrading effect of the storms themselves that could result in a higher probability of exposure in the future.

Flood Impacts

The spatial combination of physical and socioeconomic risk ultimately determines the level of adverse impacts from floods. Structures and residents located in flood-prone areas results in the loss of property, lives, and overall well-being. As noted above, the San Jacinto waste pits are uniquely situated in an area that experiences both riverine and storm surge-based flooding, resulting in major previous impacts to the surrounding community. Further compounding future impacts is the fact that both physical risk and socioeconomic profiles are changing. The primary driver of future flood loss in this region is unquestionably increasing development and associated population growth. However, changes in physical exposure, including climate change, will also increase the severity of future flood events.

This section examines the previous and projected impacts from flooding on the San Jacinto waste pits, with particular emphasis on the spatial extent of inundation around the waste pits as an indicator of potential dioxin exposure. While storms routinely claim human lives, this analysis focuses on property loss, which is the most ubiquitous and severe impact associated with flooding in the U.S. Also, inundation of property is the most likely vector for dioxin contamination and increased bioaccumulation in the environment.

Surge-Based Flooding

As noted above, flooding via storm surge is the major threat to the waste pit site and surrounding properties. The position of the site close to the mouth of a river or freshwater inflow makes it especially vulnerable given the mechanics of a storm surge. There are actually two inundation events: first, the initial rise and pulse of water inundating the waste pit site; second, the backwash of water as the surge releases back into Galveston Bay and ultimately the Gulf of Mexico. The intense tidal flushing can essentially deliver a "double dose" of pollutants to upstream residents, as well as a single downstream dose as the water returns to the Bay.

Based on the NOAA hurricane surge inundation zones (Figure 11), the waste pit site would be inundated by any hurricane and tropical storm due its low elevation and vulnerable location. Given its vulnerability, the site will almost certainly experience repetitive erosive surge events in the coming years, further degrading the structural integrity of on-site protective devices.

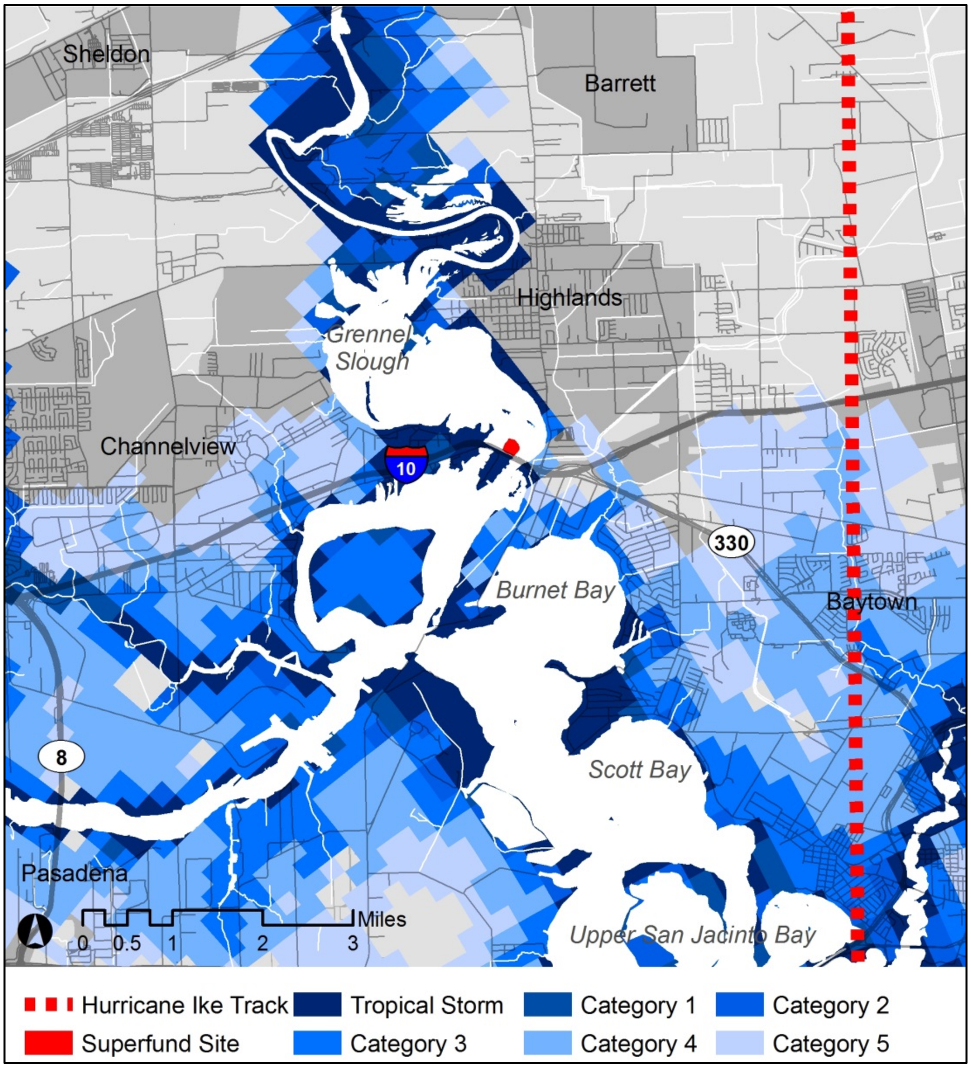


Figure 11. Surge Inundation Zones Produced by NOAA Models.

Most recently, Hurricane Ike, a strong Category 2 hurricane, made landfall in 2008 behind a very large surge event. While Ike was not even considered a 100-year storm, it caused approximately $21.3 billion in flood insurance claims (the third most costly storm in U.S. history), with the vast majority of the damage occurring in the Galveston Bay region (FEMA, 2009). This storm overwhelmed the waste pit site and could have contributed to scouring and associated leakage of dioxins detected nearby. Figure 12 shows the amount of insured residential flood loss caused by Hurricane Ike aggregated to Census Block Groups around the site. These losses totaled approximately $22.3 million in residential flood loss within approximately 5 miles of the site. The majority of these losses (up to $11 million) occurred in the neighborhoods just south of the waste pit site around Burnet Bay (Figure 12). Areas to the north of Highlands also incurred property damage as the storm surge pushed past the waste pit site and up into the San Jacinto River (see Appendix B for map of individual points of insured loss). Furthermore, analysis of a FEMA-based model for Hurricane Ike predicts the Census Block in which the waste pit site is located would experience up to $29 million in property damage.

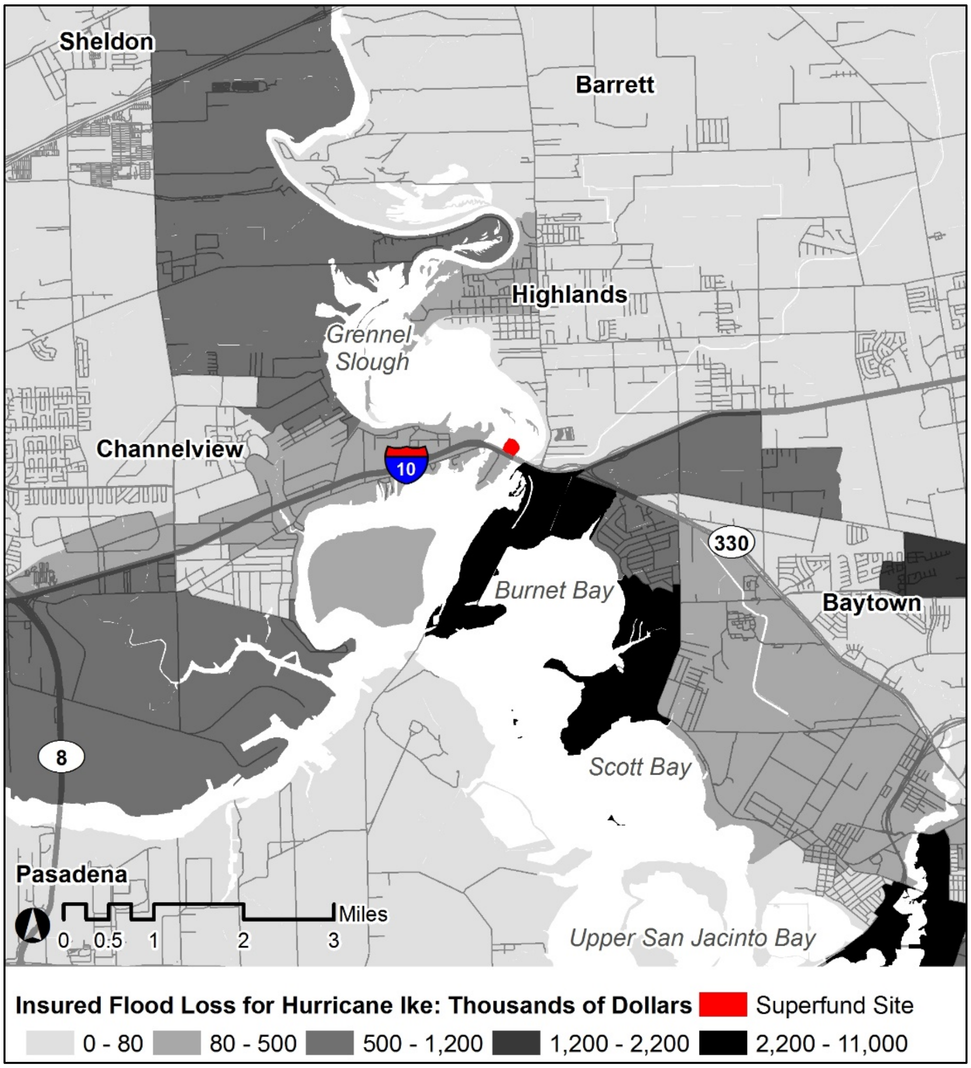


Figure 12. Insured Losses from Hurricane Ike by Census Block Group.

To further assess the future impact of storms on the waste pit site and potential inundation of surrounding neighborhoods, we predicted the extent of two storm events. First, we modelled a hurricane Ike-level storm as a baseline event currently driving mitigation policy in the Houston-Galveston region, using a SLOSH (Sea Lake and Overland Surges from Hurricane) model developed by the National Weather Service. Second, we analyzed a NOAA developed category 5 hurricane as a worst-case scenario. As shown in Figure 12, the surge associated with an Ike-type storm (demarcated in dark blue) produces an inundation height of 12 feet above sea level at the waste pit site. Based on its elevation, this synthetic storm submerges the site by nearly 10.5 feet of water. The worst-case Category 5 scenario (demarcated in light blue) not only increased surge height at the site, but also the extent of inundation, and possibly chemical exposure, to surrounding communities.

It is also important to note that critical infrastructure near the site such as schools, water reservoirs, and waste water facilities inundated by the two storm scenarios. Of particular concern is the Lynchburg

Reservoir approximately half a mile from the Superfund site. This reservoir holds about 1.5 billion gallons of water and provides drinking water to nearly 600,000 residents (Blumenthal, 2005). Ranging from 4-7 feet above sea level, the reservoir is susceptible to surge inundation from both the Hurricane Ike SLOSH scenario, and the category 5 NOAA scenario. The Ike scenario would overtop the reservoir's southern tip and portions of the western edge whereas the Category 5 hurricane would completely inundate the reservoir, potentially exposing residents to contaminants via drinking water (Figure 12).

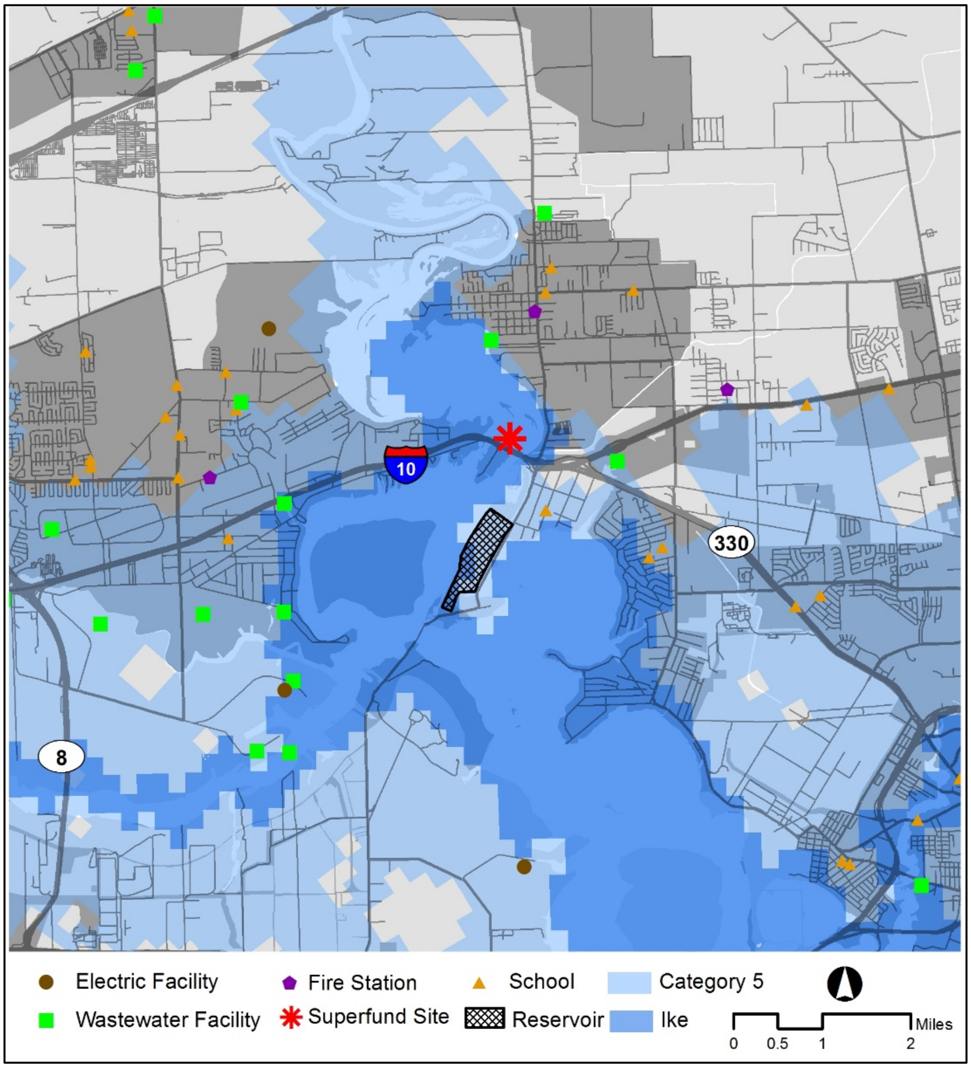


Figure 13. Surge Inundation for Hurricane Ike (using SLOSH) and a Category 5 Hurricane (using NOAA).

As mentioned above, recent development sprawling from Houston has dramatically increased the number of people near the superfund site. If the existing cap were to fail, surge near the site could potentially expose residential parcels to dioxin-laden soils. Key areas of focus are north of the site as hurricane surge tends to push water up the San Jacinto River. Based on the spatial extent of inundation produced by the two scenarios above, we summarized the number of residential parcels impacted for the HGAC land use maps for years 2014 and 2040 (Figure 13). Based on current land use surrounding the waste pit site, 81 properties would be affected by a storm surge similar to Hurricane Ike. A category 5 storm surge would increase the affected parcels to 750. If the same storm were to hit the area in 2040, nearly ten times as many parcels north of the waste site would be inundated (1,085 parcels), a storm similar to Hurricane Ike would inundate 115 parcels (Figure 13).

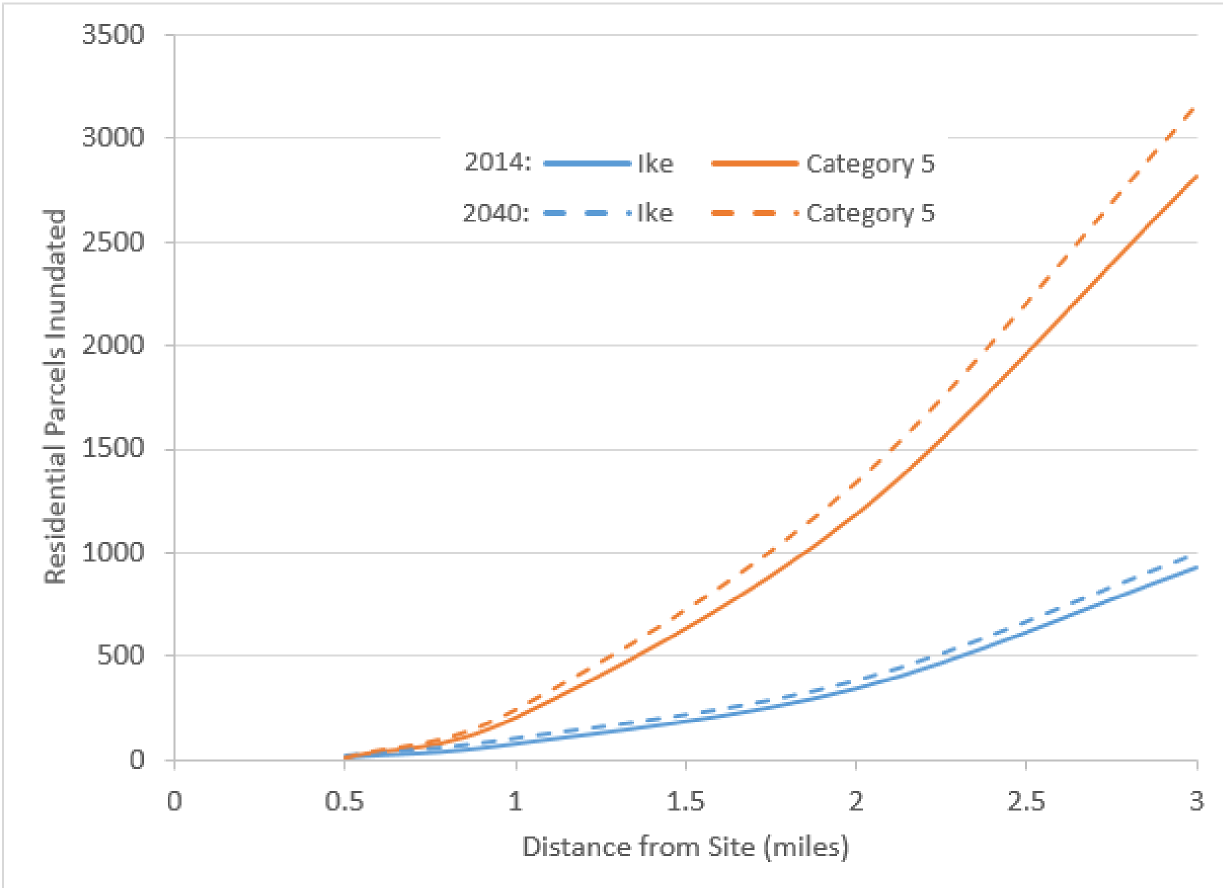


Figure 14. Number of Residential Parcels Inundated by Hurricane Ike and Category 5 scenarios.

Freshwater Flooding

It should also be noted that the San Jacinto waste pits are also vulnerable to damaging high-peak flows from regional runoff. Frequent large rainfall events can easily submerge the waste pits, causing them to overtop their levees and possibly spill contaminants into the San Jacinto River. Historical crest records from a USGS gage indicate that the waste pits have been exposed to potentially high-scouring flows at least 27 times since 1973 (Bedient, 2013). During these events the waste pits can remain submerged under water for days at a time. In 2001, for example, Tropical Storm Allison dropped over 18 inches of rain in this region, causing at the time one of the costliest tropical storms in US history (Stewart, 2001). During this storm, water flooded residential structures as a result of swelling rivers and streams or from local ponding. If the event was strong enough, dioxin-laden soil could have been scoured from the site and deposited into local residential structures; however, it would likely be diluted at that point. As shown in Figure 15, the majority of impacts (up to $1.5 million) from rainfall-based storms occurred to the northeast and southeast of the waste pit site when the San Jacinto River and Ship Channel crested their banks.

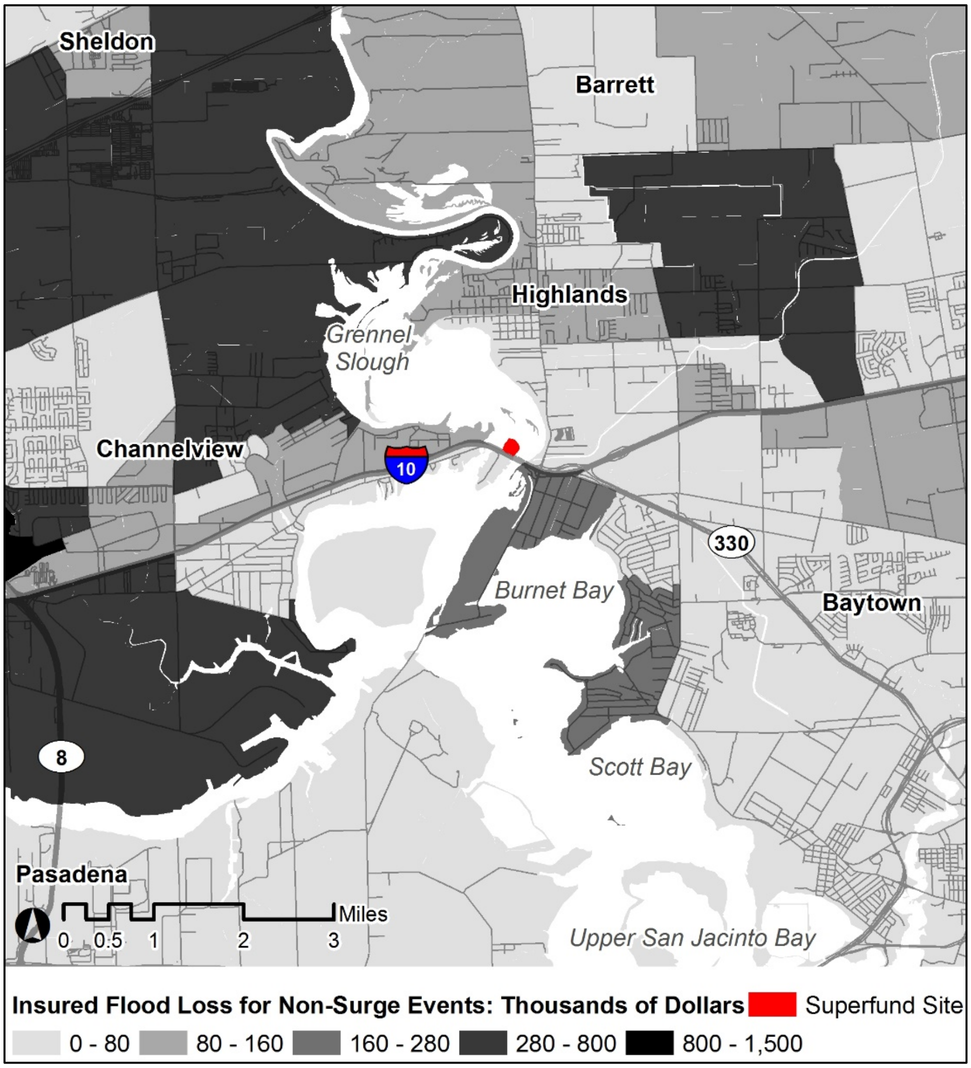


Figure 15. Insured Losses for Freshwater Flooding, 1999-2009.

CONCLUSION

The San Jacinto Waste Pits are located in an area that is vulnerable to many different physical threats: hurricane surge, wave action, riverine flooding, subsidence, and sea level rise. These forces, over time, have eroded the sediment and embankments around the site, which are likely the primary reasons for the eventual leakage of the toxic chemicals into the surrounding environment. The threat of human exposure when this site was built during the 1960's was much lower than it is today. Historical development has rapidly increased the amount of people that live within a few miles of the site and this trend is projected to continue well into the future.

More serious attention needs to be given to the local socioeconomic and built environment characteristics of this hazardous site. The threat of future surge and riverine flood events coupled with a changing climate and increasing development all have a ratcheting effect on the amount of impact this superfund site could inflict on surrounding communities. As risk of failure increases so too does the risk of exposure from flood-induced water vectors. Bioaccumulation is already occurring exposing local fisherman and residents to harmful chemicals that consume the fish and crabs. Sediment contaminated with dioxins could potentially be scoured from the site and transported into neighboring residential areas, school and wastewater management facilities, and a reservoir that provides drinking water. That said, the installation of the temporary geomembrane by the EPA is a first attempt to prevent leaking and exposure, but this is likely the first of many repairs that are likely to occur due the vulnerable location of this site.

Based on the flood risk assessment above, it is my expert opinion that the waste pits should be fully removed as outlined by Alternative 6 in the Feasibility Study conducted for CIMC and International Paper, Inc. (Anchor QEU, 2013). As already mentioned, the site is in an extremely vulnerable location to repeated inundation, which will only increase in the future. There is insufficient evidence that any proposed on-site remediation alternative can effectively stabilize the pits over the long term and prevent the leakage of contaminants to surrounding areas. The information contained in this report provides a more complete understanding of the flood risks associated with the site and can offer guidance to decision makers as they contemplate future mitigation actions.

WORKS CITED

Akhtar F, Garabrant D, Ketchum N, Michalek J. (2004). Cancer in US Air Force veterans of the Vietnam war. *J Occup Environ Med* 46: 123-13.

Anchor QEA, LLC. (2013). Draft Feasibility Study Report: San Jacinto Waste Pits Superfund Site. Prepared for McGinnes Industrial Maintenance Corporation and International Paper Company. August 2013.

ATSDR. (2012). Public Health Assessment. San Jacinto River Waste Pits Channelview, Harris County, Texas. EPA Facility ID: TXN000606611 October 30, 2012.

Bertazzi PA, Consonni D, Bachetti S, Rubagotti M, Baccarelli A, Zocchetti C, et al. (2001). Health effects of dioxin exposure: a 20-year mortality study. *Am J Epidemiol* 153: 1031–1044.

Bawden GW, Sneed M, Stork SV, Galloway DL .(2003). Measuring human-induced land subsidence from space. USGS Fact Sheet 069-03. http://pubs.usgs.gov/fs/fs06903/

Beauchamp, R.A. (2013). San Jacinto River Waste Pits Superfund Site - Exposure Pathways Analysis. Texas Department of State Health Services and Agency for Toxic Substances & Disease Registry.

Blumenthal, R. (2005). Houston Narrowly Avoids a Water Crisis. New york Times.

Brody, S. D., S. Zahran, W. E. Highfield, H. Grover and A. Vedlitz. (2008). Identifying the impact of the built environment on flood damage in Texas. *Disasters* 32(1): 1-18.

Cutter, S. L. and C. T. Emrich. (2006). Moral hazard, social catastrophe: The changing face of vulnerability along the hurricane coasts. *The Annals of the American Academy of Political and Social Science* 604(1): 102-112.

Federal Emergency Management Agency. (2009). Mitigation Assessment Team Report: Hurricane Ike in Texas and Louisiana. FEMA P-757.

Galveston Bay Foundation. (2014). San Jacinto River Waste Pits Superfund Site. http://galvbay.org/advocacy_sjrwp.html Accessed 06/04/14.

Haynes, D. and Johnson, J.E. (2000). Organochlorine, heavy metal and polyaromatic hydrocarbon pollutant concentrations in the Great Barrier Reef (Australia) environment: a review. *Marine Pollutant Bulletin* 41: 7-12.

Houston-Galveston Area Council. (2013). Regional Land Use Information System (Regional Growth Forecast).

Harris County Flood Control District. San Jacinto River Watershed. http://www.hcfcd.org/L_sanjacriver.html Accessed 06/04/14.

Houston Galveston Subsidence District. (2014). http://www.hgsubsidence.org/index.html. Accessed 05/20/2014.

Houston, C. O. (2014). Houston Facts and Figures. http://www.houstontx.gov/abouthouston/houstonfacts.html. Retrieved 5/22/2014.

Trungale Engineering and Science. (2007). Instream Flow Targets for the Trinity and San Jacinto River Basins Senate Bill 3: Environmental Water Planning. Prepared for: National Wildlife Federation.

Integral Consulting Inc. (2010). Technical Memorandum on Bioaccumulation Modeling: San Jacinto River Waste Pits Superfund Site. Prepared for: McGinnes Industrial Maintenance Corporation, International Paper Company, and U.S. Environmental Protection Agency, Region 6.

Integral and Anchor QEA. (2013). Remedial Investigation Report. Prepared of U.S. Environmental Protection Agency, Region 6, on behalf of McGinnes Industrial Maintenance Corporation and International Paper Company. May 2013.

Kransler, K.M., McGarrigle, B.P. and Olson, J.R. (2007). Comparative Developmental Toxicity of 2,3,7,8-tetracholorodibenzo-p-dioxin in the Hamster, Rat and Guinea Pig. *Toxicology* 229: 214-225.

Keim, B. D., Muller, R. A., & Stone, G. W. (2007). Spatiotemporal patterns and return periods of tropical storm and hurricane strikes from Texas to Maine. *Journal of Climate 20*(14).

Leos, Valmichael. (2014). San Jacinto River Waste Pits TCRA. United States Environmental Protection Agency: On-Scene Coordinator. http://www.epaosc.org/site/site_profile.aspx?site_id=6534. Accessed 06/04/14.

Micheletti, C., Critto, A., and Macromini, A. (2007). Assessment of ecological risk from bioaccumulation of PCDD/Fs and dioxin-like PCBs in a coastal lagoon. *Environment International* 33: 45 – 55.

Martin, D.M., T. Morton, T. Dobrzynski, and B. Valentine. (1996). Estuaries on the Edge: The Vital Link Between Land and Sea. A Report by American Oceans Campaign. http://www.americanoceans.org/estuary/edge.htm.

Papke, O. (1998). PCDD/PCDF: Human Background Data for Germany, a 10-year experience. *Environmental Health Perspectives* 106 (S2): 723-731.

Patandin, S., Dagnelie, P.C., Mulder, P.G.H., Op de Coul, E., van der Veen, J.E., Weisglas-Kuperus, N., and Sauer, P.J.J. (1999). Dietary exposure to polychlorinated biphenyls and dioxins from infancy until adulthood: A comparison between breast-feeding, toddler and long-term exposure. *Environmental Health Perspectives* 107 (1): 45-51.

Pasadena Citizen, The. (2014). Ryan urges EPA to require complete dioxin removal from San Jacinto River waste pits (2014, May 10) *The Pasadena Citizen*. http://www.yourhoustonnews.com/pasadena/news/ryan-urges-epa-to-require-complete-dioxin-removal-from-san/article_3c5965be-b414-55ad-991e-6eab8c70e339.html

Peacock, W. G., H. Grover, J. Mayunga, S. Van Zandt, S. D. Brody, H. J. Kim and R. Center. (2011). The status and trends of population social vulnerabilities along the Texas Coast with special attention to the Coastal Management Zone and Hurricane Ike: The Coastal Planning Atlas and Social Vulnerability Mapping Tools, A report prepared for the Texas General Land Office and The National Oceanic and Atmospheric Administration. College Station, TX: Texas A&M University.

Pulsinelli, O. (2013). Population Boom lands Houston on Fastest growing list. Houston Business Journal. http://www.bizjournals.com/houston/news/2013/03/14/houston-harris-county-among.html?page=all. Retrieved 5/12/2014.

Rifai H, P.I. (2006). Total Maximum Daily Loads for Dioxins in the Houston Ship Channel, Quarterly Report No. 3. University of Houston, July 2006.

Ronk, J. and Guven, B. (2013) San Jacinto River Waste Pits Superfund Site Technical Document Review: May 2013 Baseline Ecological Risk Assessment. Houston Advanced Research Center.

San Jacinto River Authority. (1957). Master Plan Report for the Full Scale Development of the San Jacinto River Authority. Conroe, Texas.

Schecter, A., Startin, J., Wright, C., Kelly, M., Papke, O., Lis, A., Ball, M., and Olson, J.R. (1994). Congener specific levels of dioxins and dibenzofurans in U.S. food and estimated daily dioxin toxic equivalent intake. *Environmental Health Perspectives* 102: 962-966.

Schecter, A., Papke. O., Lis, A., Ball, M., Ryan, J.J., Olson, J.R., Li, L., and Kessler, H. (1996). Decrease in milk and blood dioxin levels over two years in a mother nursing twins: Estimates of decreased maternal and increased infant dioxin body burden from nursing. *Chemosphere* 32(3): 543-549.

Shroeder, Paul R. (2013). Review of Design, Construction and Repair of TCRA Armoring for West Berm of San Jacinto Waste Pits. Prepared for the U.S. Environmental Protection Agency, Region 6. US Army Corps of Engineers: Engineer Research and Development Center.

Stephen, F.D., Greizerstein, H., Kostyniak, P.J., Mendola, P., Vena, J.E., Buck, G.M., and Olson, J.R. (1998). Effects of exposure to Great Lakes contaminants on immune parameters in Lake Ontario Anglers. *The Toxicologist* 42: 97.

Stewart, Stacy R. (2001). "Tropical Cyclone Report Tropical Storm Allison." National Hurricane Center. http://www.nhc.noaa.gov/2001allison.html. Retrieved: May 30th, 2014.

Torres, M.A., Barros, M.P., Campos, S.C.G., Pinto, E., Rajamani, S., Sayre, R.T., Colepicolo, P. (2008). Biochemical biomarkers in algae and marine pollution. *Ecotoxicology and Environmental Safety* 71: 1-15.

Texas Commission on Environmental Quality. (2014). San Jacinto River Tidal: A Project for Legacy Pollutants in Fish. http://www.tceq.texas.gov/waterquality/tmdl/47-sanjacintolegacy.html. Accessed on May, 28th 2014.

Texas Department of State Health Services: Fish and Shellfish Consumption Advisory. (2013). ADV-50.

U.S. Department of Health and Human Services. (2014) Poverty Guidelines. http://aspe.hhs.gov/poverty/14poverty.cfm. Accessed 05/23/14

United States Environmental Protection Agency. (1999). Polychlorinated Dibenzo-p-dioxins and Related Compounds Update: Impact of Fish Advisories.

United States Environmental Protection Agency. (2012). San Jacinto River Waste Pits. http://www.epa.gov/region6/6sf/texas/san_jacinto/. Accessed 06/04/14.

Vena, J.E., Bucl, G.M., Kostyniak, P., Mendola, P., Fitzgerald, E., Sever, L., Freudenheim, J., Greizerstein, H., Zielezny, M., McReynolds, J. and Olson, J. (1996). The New York Angler Cohort Study: Exposure Characterization and Reproductive and Developmental Health. *Toxicology and Industrial Health* 12(3/4): 327-334.

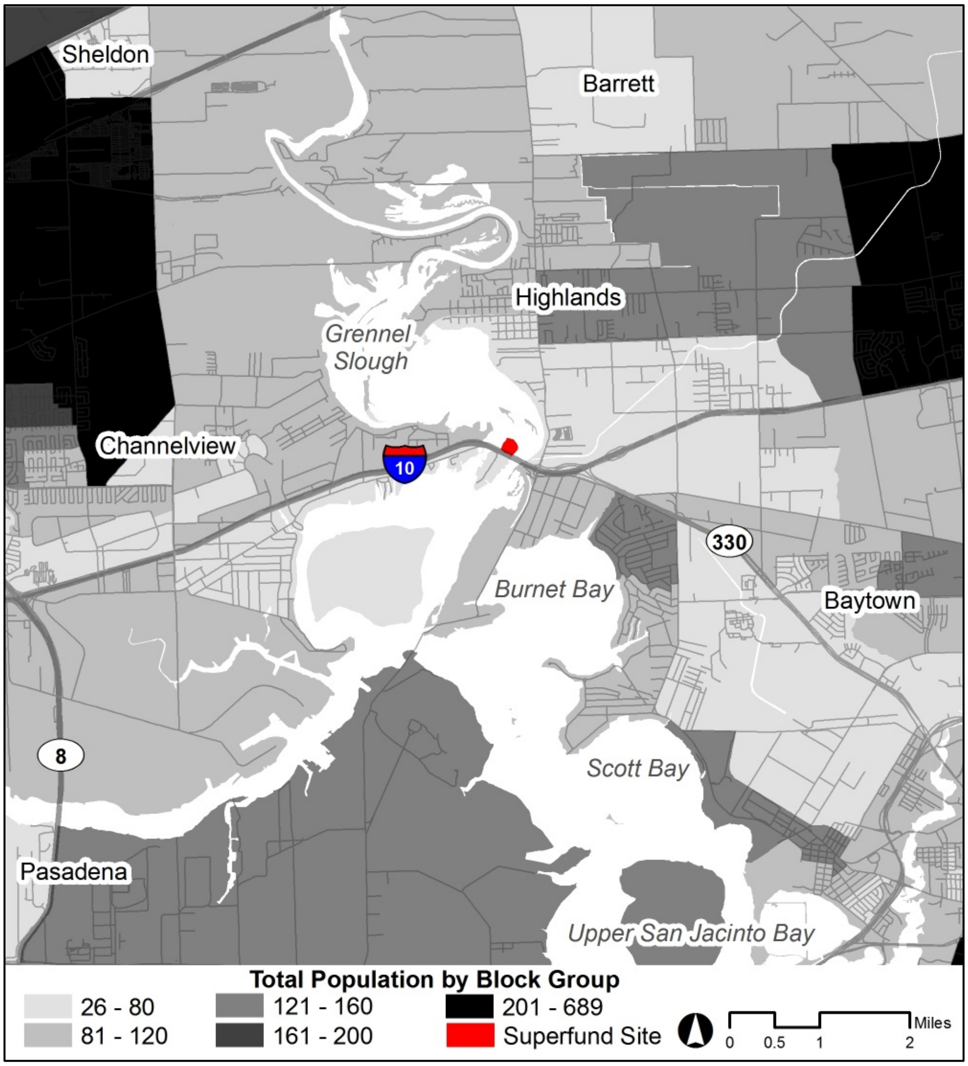
Yoskowitz, D. W., Gibeaut, J., & McKenzie, A. (2009). The Socio-Economic Impact of Sea Level Rise in the Galveston Bay Region. Corpus Christi, TX: A report for the Environmental Defense Fund. Harte Research Institute for Gulf of Mexico Studies, Texas A&M University. Available online at http://seg. tamucc.edu.

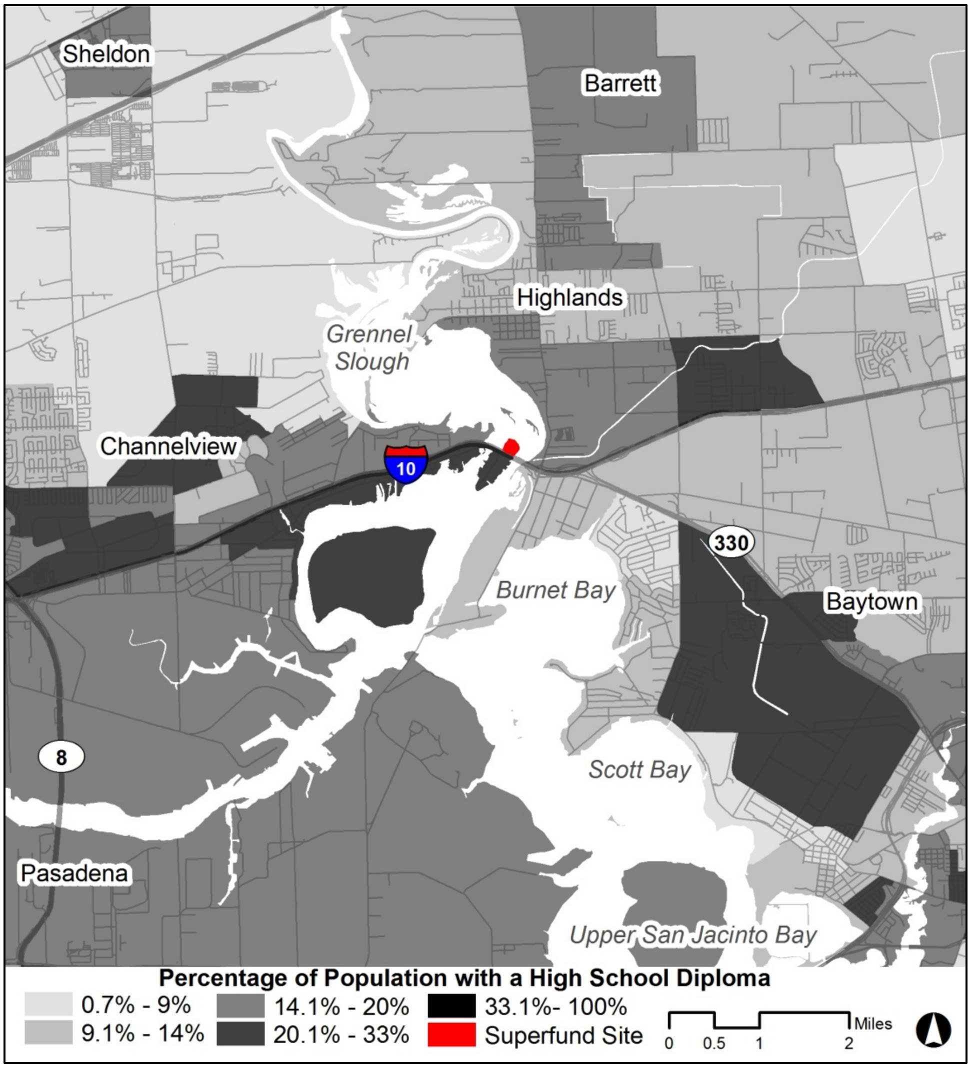
Warner, N. N., & Tissot, P. E. (2012). Storm flooding sensitivity to sea level rise for Galveston Bay, Texas. *Ocean Engineering 44*: 23-32.

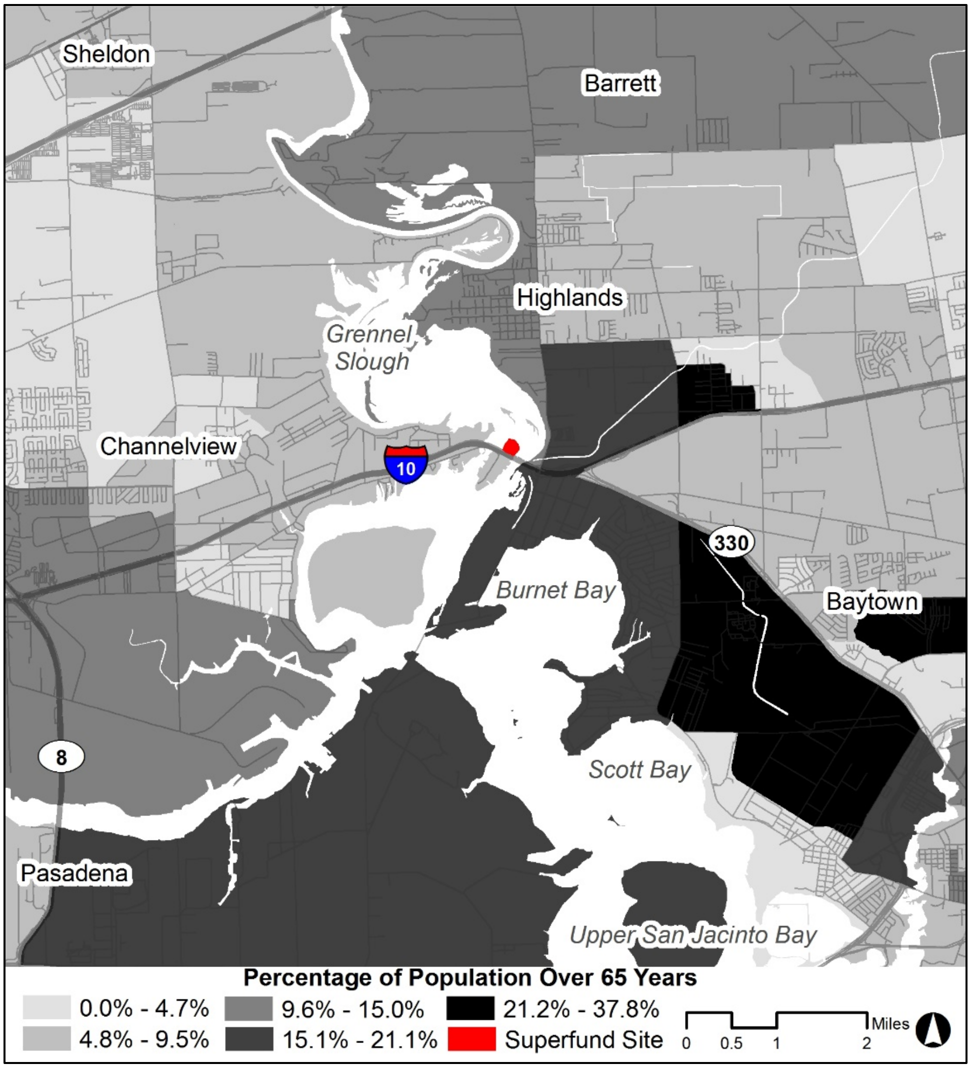
Zahran, S., S. D. Brody, W. G. Peacock, A. Vedlitz and H. Grover. (2008). Social vulnerability and the natural and built environment: a model of flood casualties in Texas. *Disasters* 32(4): 537-560.

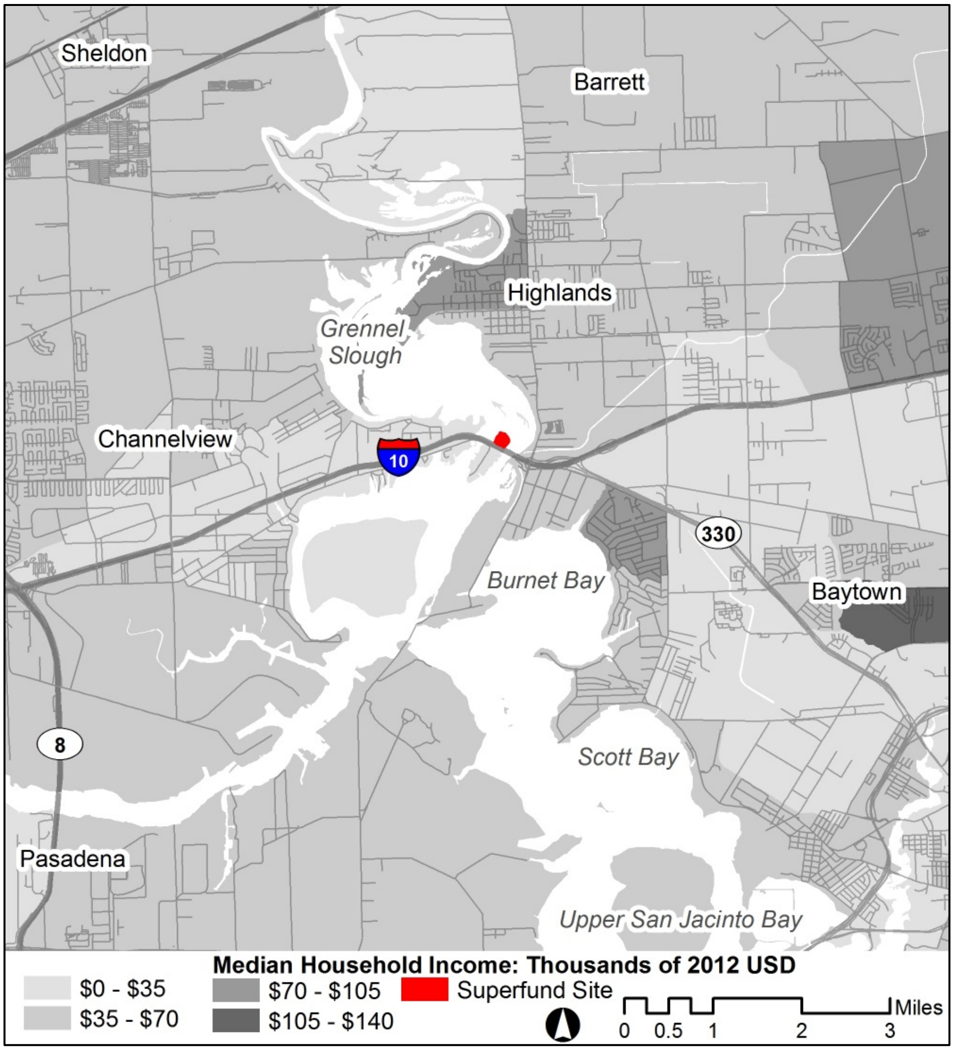
APPENDIX

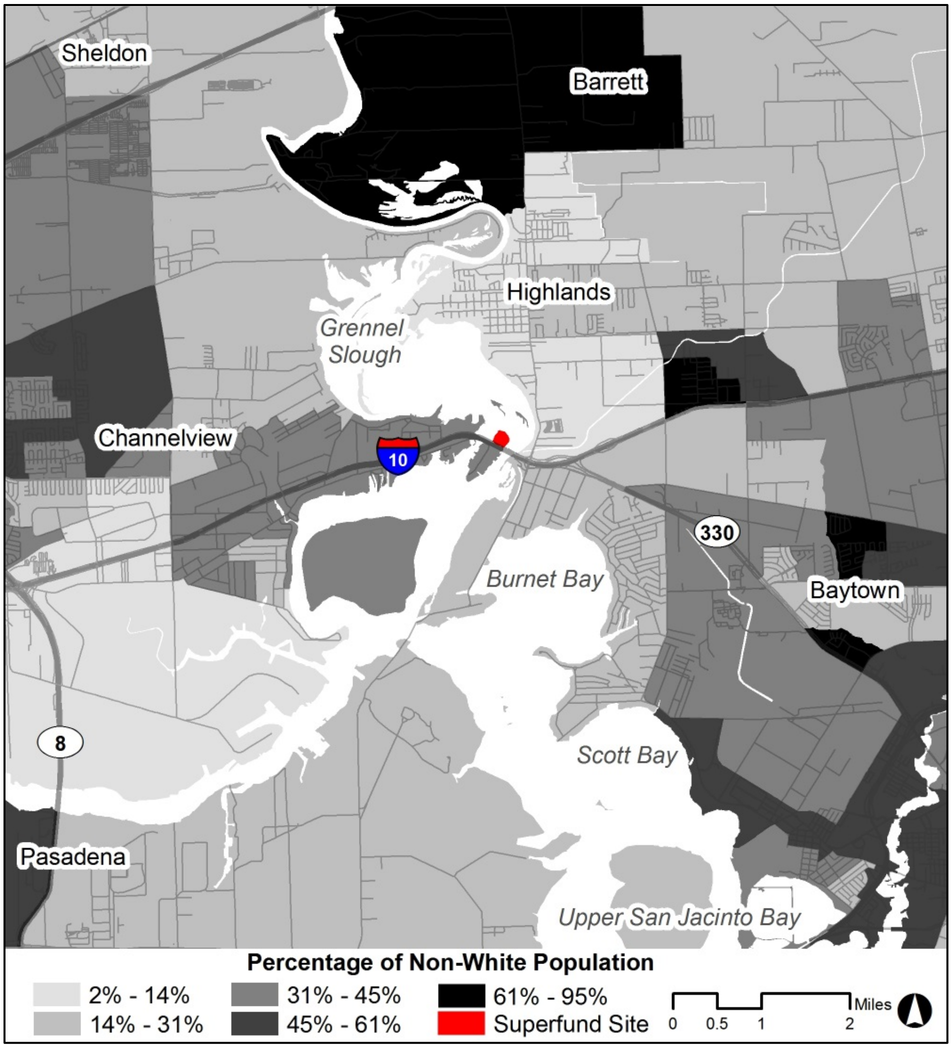
A. Social Vulnerability Index Variable Maps



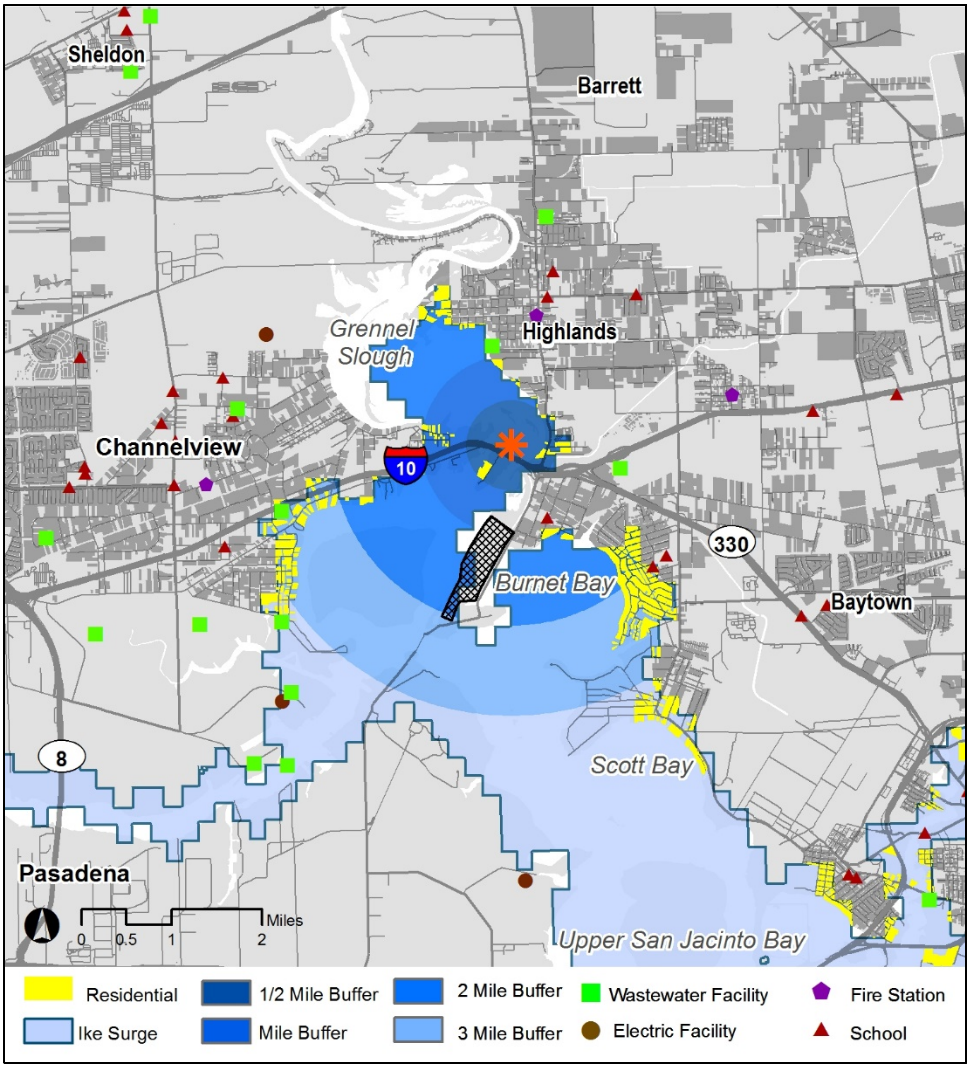

Sheldon
Barrett
Highlands
Grennel Slough
Channelview
10
330
Burnet Bay
Baytown
8
Scott Bay
Pasadena
Upper San Jacinto Bay
Percentage of Population with a High School Diploma
0.7% - 9%
9.1% - 14%
14.1% - 20%
20.1% - 33%
33.1%- 100%
Superfund Site
Miles
0
0.5
1
2


Sheldon
Barrett
Highlands
Grennel Slough
Channelview
10
330
Burnet Bay
Baytown
8
Scott Bay
Pasadena
Upper San Jacinto Bay
Percentage of Population Over 65 Years
0.0% - 4.7%
4.8% - 9.5%
9.6% - 15.0%
15.1% - 21.1%
21.2% - 37.8%
Superfund Site
Miles
0
0.5
1
2

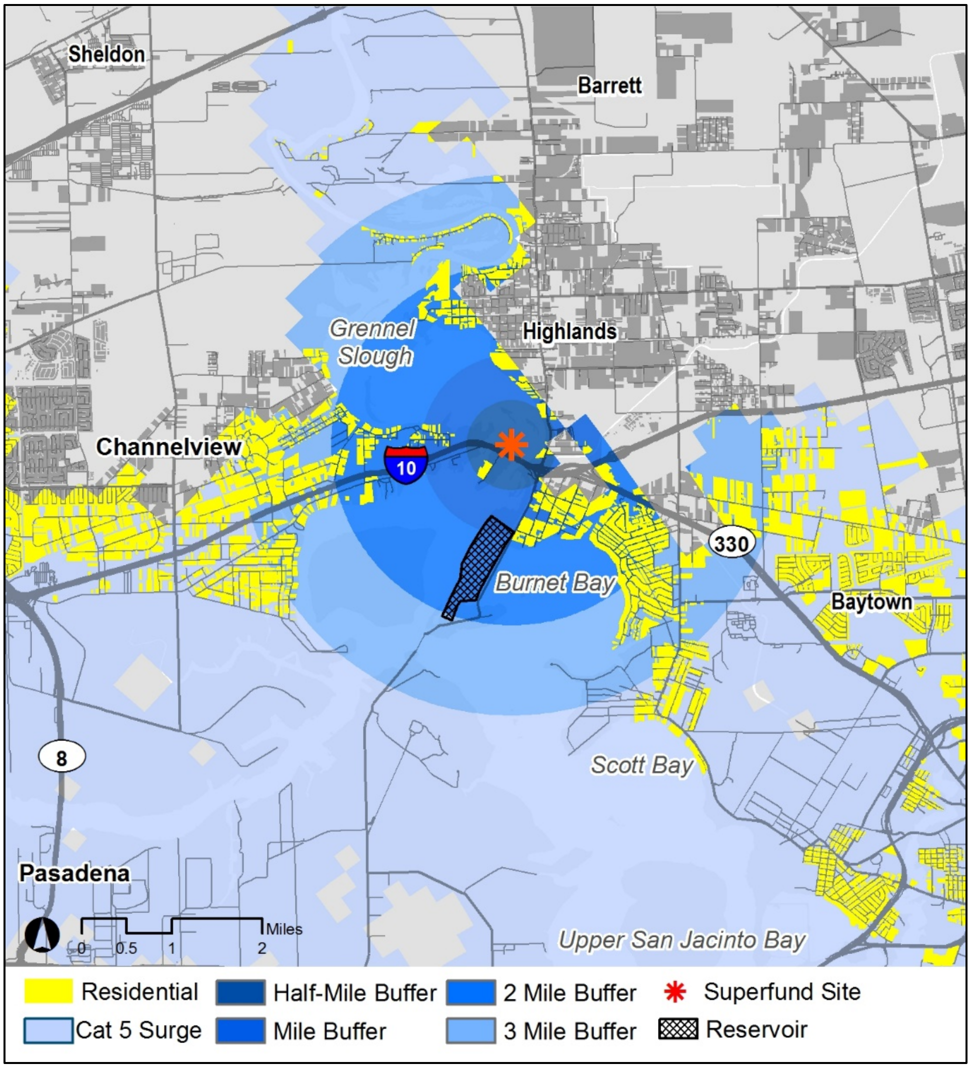

Sheldon
Barrett
Highlands
Grennel Slough
Channelview
10
330
Burnet Bay
Baytown
8
Scott Bay
Pasadena
Upper San Jacinto Bay
Median Household Income: Thousands of 2012 USD
$0 - $35
$35 - $70
$70 - $105
$105 - $140
Superfund Site
0 0.5 1 2 3
Miles


Sheldon
Barrett
Highlands
Grennel Slough
Channelview
10
330
Burnet Bay
Baytown
8
Scott Bay
Pasadena
Upper San Jacinto Bay
Percentage of Non-White Population
2% - 14%
14% - 31%
31% - 45%
45% - 61%
61% - 95%
Superfund Site
0 0.5 1 2
Miles

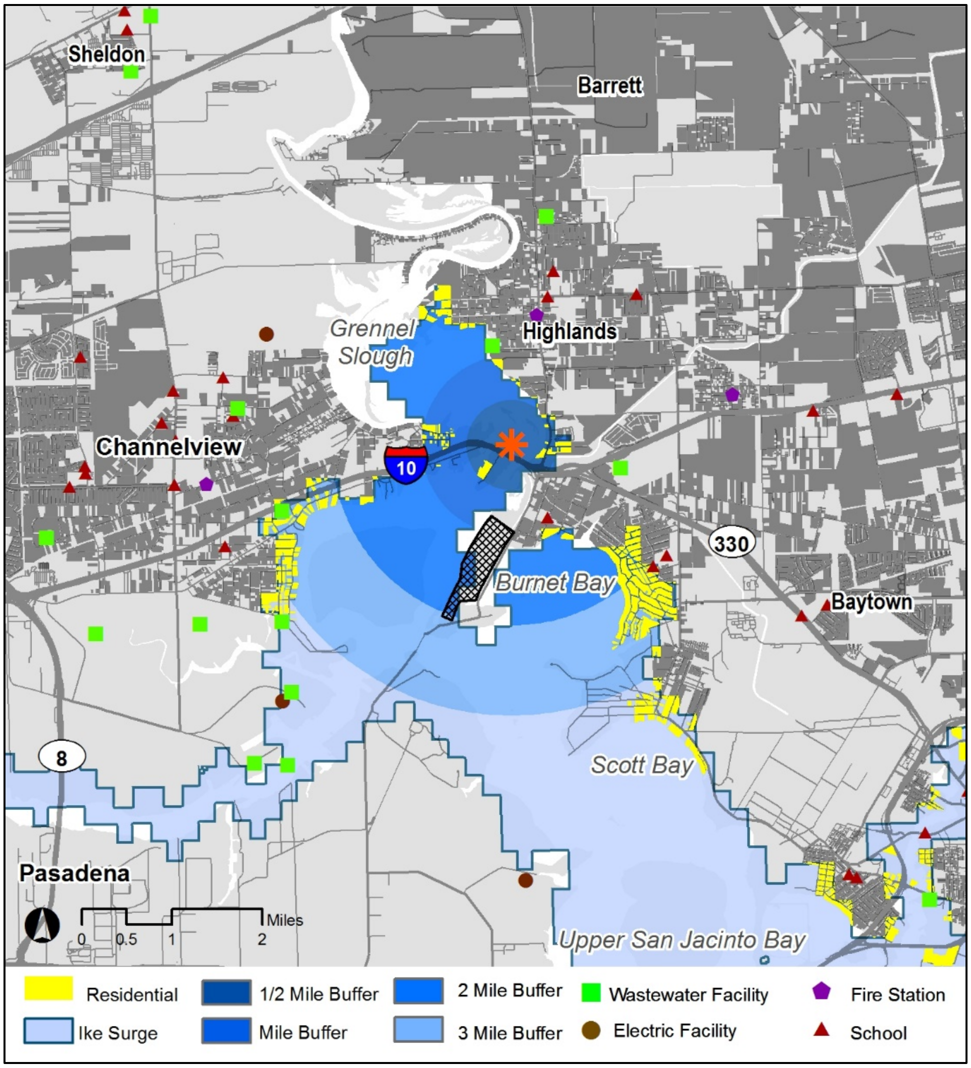
B. Flood Impact Analyses



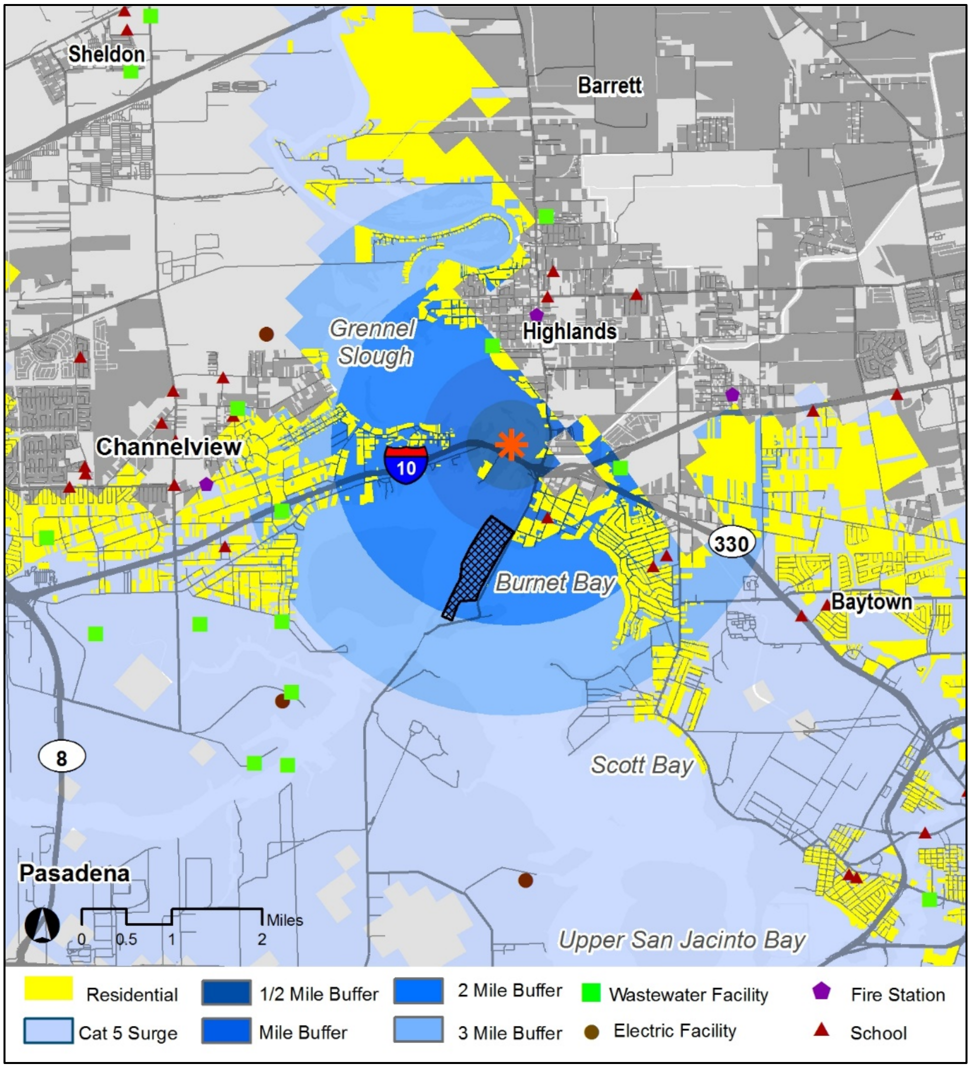
Current Residential Land Use Ike Inundation



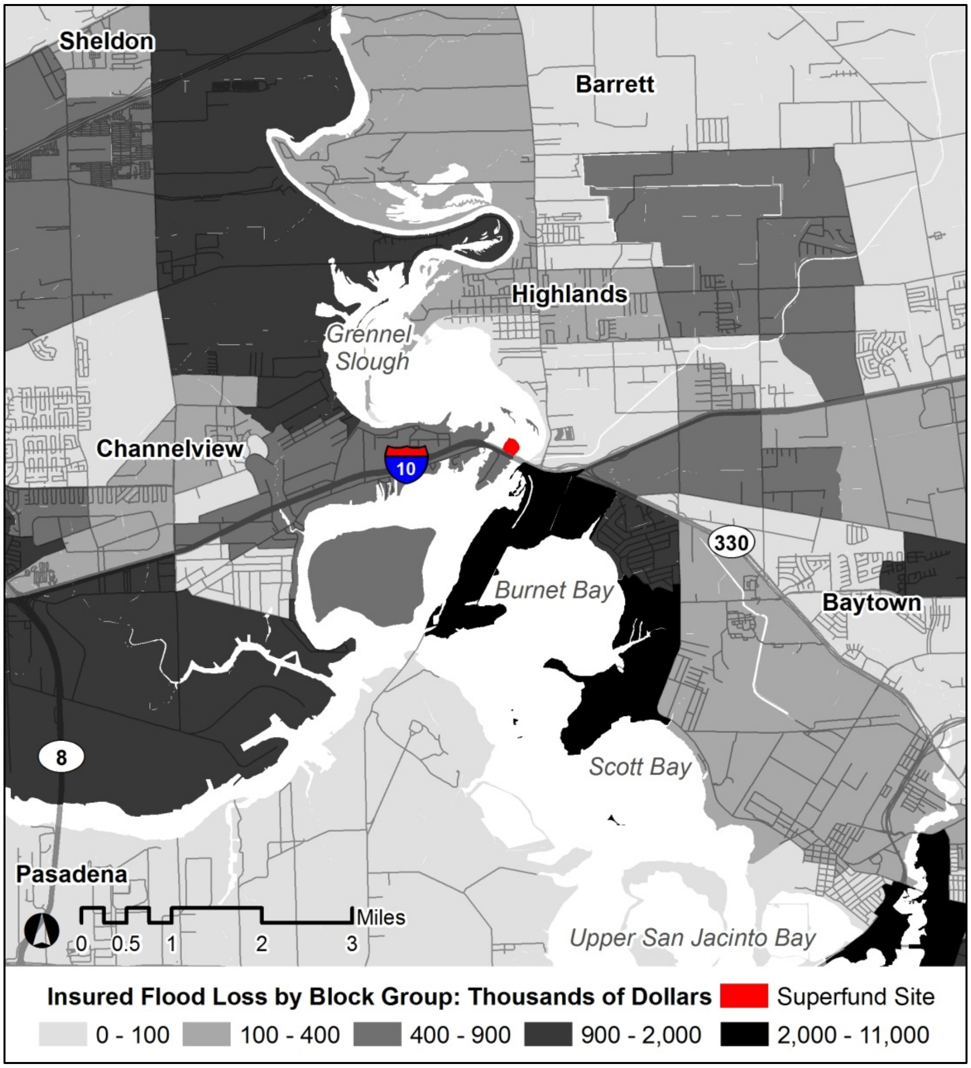
Current Residential Land Use Category 5 Inundation



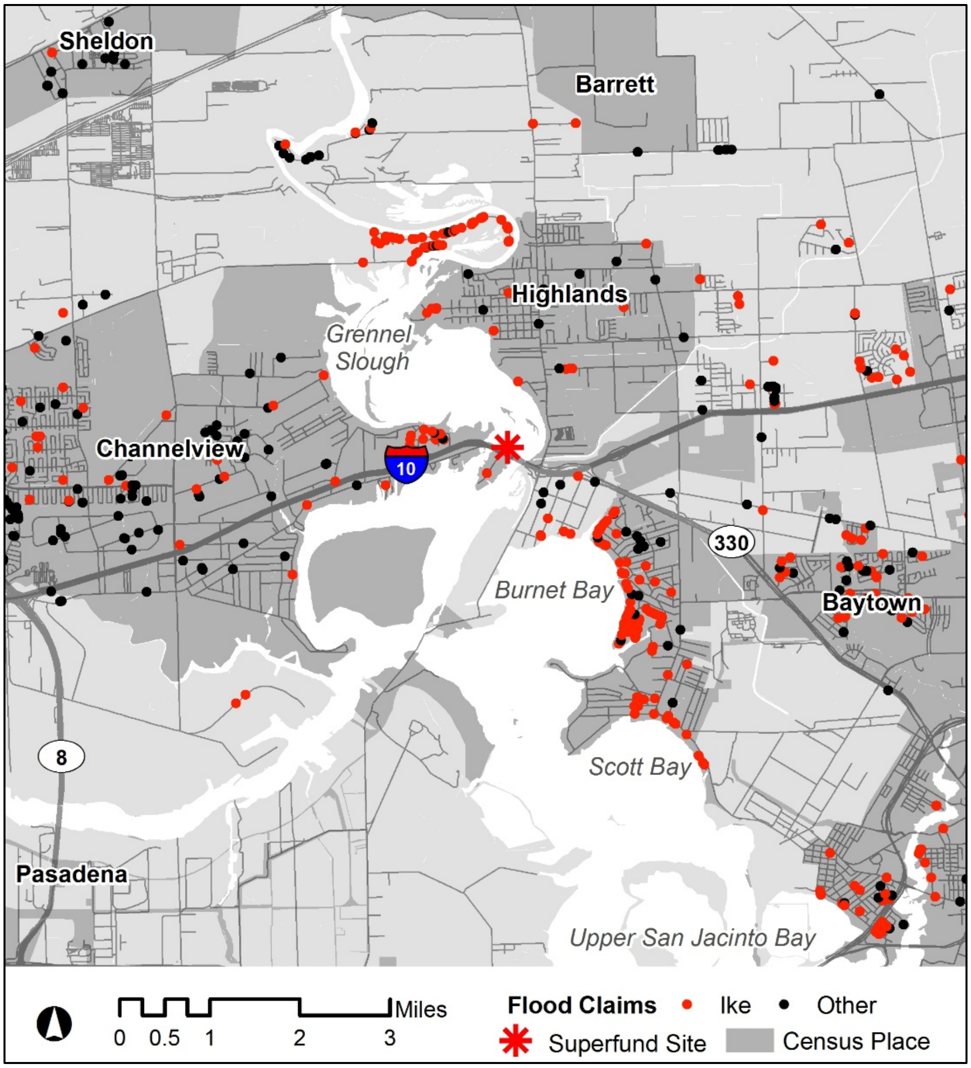
Future Residential Land Use Ike Inundation



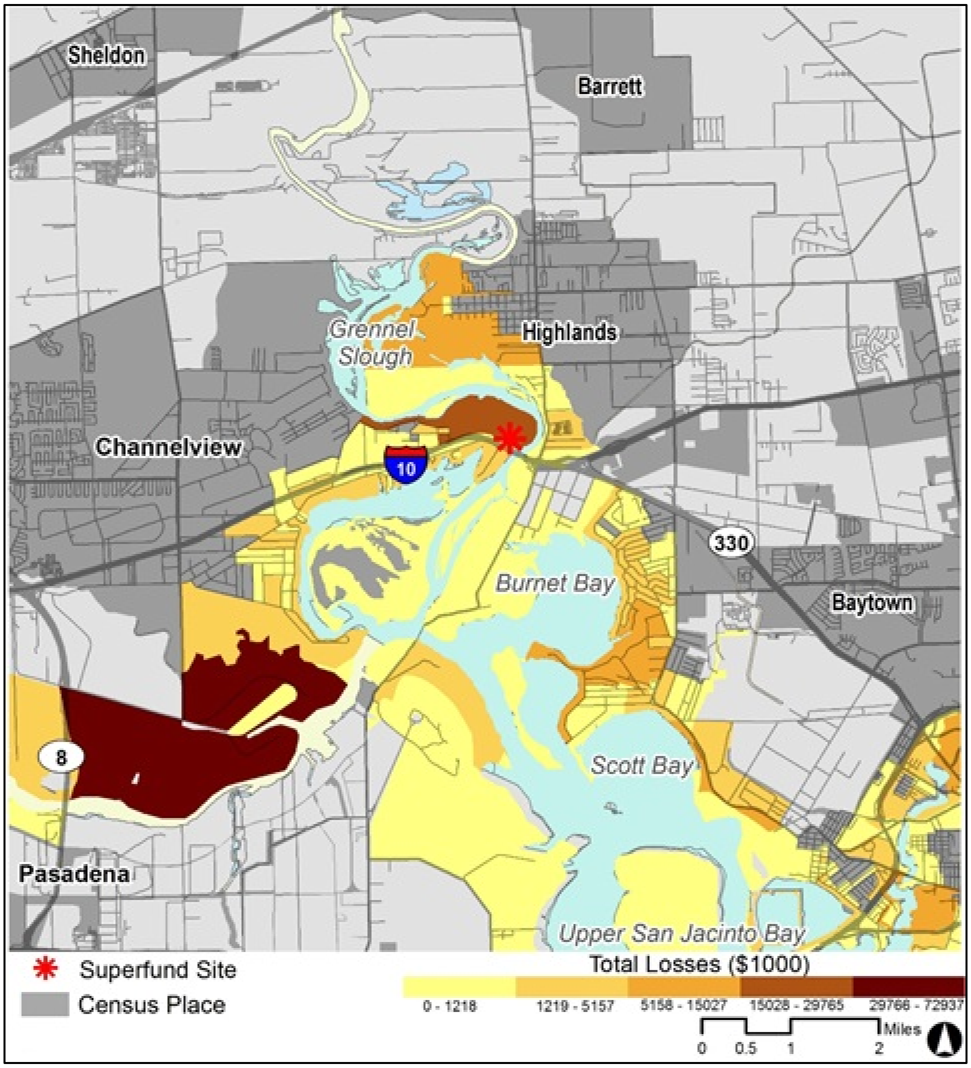
Future Residential Land Use Category 5 Inundation



Insured Residential Flood Loss by Census Block Group, 1999 to 2009.



Insured Residential Flood Loss, 1999 to 2009



HAZUS-MH loss estimation for a synthetic Hurricane Ike scenario